OUTLINES

OF

COMPARATIVE ANATOMY.

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COMPARATIVE ANATOMY,

PRESENTING A SKETCH OF THE PRESENT STATE OF KNOWLEDGE, AND OF THE PROGRESS OF DISCOVERY, IN THAT SCIENCE; AND DESIGNED TO SERVE AS AN INTRODUCTION TO ANIMAL PHYSIOLOGY, AND TO THE PRINCIPLES OF CLASSIFICATION IN ZOOLOGY.

BY

ROBERT E. GRANT, M.D.

F.R.S. L. & Ed. F.L.S. F.G.S. F.Z.S. M.W.S. &c.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS OF EDINBURGH, LATE PROFESSOR OF PHYSIOLOGY IN THE ROYAL INSTITUTION OF GREAT BRITAIN, AND PROFESSOR OF COMPARATIVE ANATOMY AND ZOOLOGY, IN UNIVERSITY COLLEGE, LONDON.

CONTAINING

PART FIRST,

Organs of Relation or of Animal Life,

AND

PART SECOND,

Organs of Vegetative or Organic Life.

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CHAPTER FIRST.

ORGANS OF SUPPORT, OR OSSEOUS SYSTEM.

FIRST SECTION.

General Observations on the Osseous System of Animals.

As animals are organized to select and obtain foreign matter for their subsistence, and to convey it into their digestive organs, to be transported with them from place to place, they generally require some solid means of support for the attachment of their active organs of motion. These denser parts of the body serve as a solid frame-work to give form and solidity to the whole fabric, and to protect the more delicate organs. They consist for the most part of earthy materials separated from the food by the vital processes of the animal, and may be placed on the exterior or in the interior of the soft parts. These inert materials, or passive organs of locomotion receive their forms from those of the soft parts, and are liable to change with the varying conditions of the contiguous living parts. When placed on the exterior of the body, they may, without being organized,

keep pace with the progress of growth in the living parts, by being periodically cast off and renewed; or they may increase by the addition of more extended layers to their surface; or their dimensions may be continually influenced by the contact of the parts which formed them. But when this solid frame-work is internal, and is everywhere surrounded by the soft parts, giving attachment to muscles, or enveloping and protecting delicate organs, it cannot be conveniently removed from the system in a mass, nor preserve its proportions by the mechanical addition of layers to its surface, and is generally organized or permeated in every point by the soft parts which absorb the decayed materials and renew them particle by particle. The earthy materials thus formed by animals for the support of their soft parts are various, and their particles are generally united together by means of a condensed albuminous or gelatinous matter, which gives firmness and tenacity to the mass. Silica is found in the lowest forms of radiated animals; carbonate of lime in the molluscous classes; carbonate and phosphate of lime in the articulated animals, and phosphate of lime in the organized skeletons of the vertebrata. These earths, in consolidating, assume forms by the influence of laws which are in accordance with their ordinary physical properties, this we observe most obviously in the lowest animals, and least in the highest classes where the crystalline arrangement of the particles is most equivocal; but under every condition they alike form a normal part of the structure, a solid frame-work more or less complete, constant in its form and structure in the same species, and varying in its form with the specific differences of animals. This solid framework forms the osseous system of animals, or the *skeleton*, as it has been termed from the dry and earthy nature of the materials which compose it. The osseous system, though not the most important nor the most universal system of animal organization, is met with under some form in every class of the animal kingdom, though not in all the animals of each class.

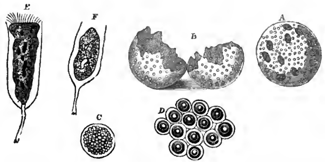
SECOND SECTION.

Organs of Support in the Radiated, or Cyclo-neurose Classes.

THE skeletons are as various as the forms of the animals in this lowest division of the animal kingdom, and scarcely indicate in their composition or structure a determinate plan common to the whole. They are sometimes external, most frequently internal, often composed of minute pieces symmetrically arranged, or of one solid mass, often of a thin flexible diaphanous horny consistence, or composed of dense silicious or calcareous spicula, or of masses of carbonate with a little phosphorate of lime. The osseous parts in these classes appear to be extravascular, and to grow by the juxtaposition of new portions, and from the simplicity of the general structure and functions of these animals, and the internal situation of their solid parts, they are not exuviable.

I. *Polygastrica.*—Many of the minute and soft polygastric animalcules possess an exterior firm, elastic covering, which protects the more delicate internal parts. This covering sometimes consists only of a more condensed form of the common integument, enveloping every part of the body, in others it forms a distinct thin pellucid sheath into which the animal can withdraw its soft parts for protection. The exterior surface, even of the softest and most naked animalcules, supports the organs of motion—the minute vibratile cilia by which they are carried to and fro, and consists apparently of a thin film of the general cellular tissue of their body, rendered more firm in its texture by the continued action of the surrounding element. This condensation of the exterior integument is the origin of most of the skeletons of invertebrated animals, which have generally the organs of support thrown over the surface of their body to afford them at the same time protection. We have an example of one of these loricated animalcules in the *volvox globator*, (Fig. 1. A) so common in stagnant pools of fresh water, and which often owe their green colour to the abundance of this animalcule. This sperical transparent green

FIG. I.



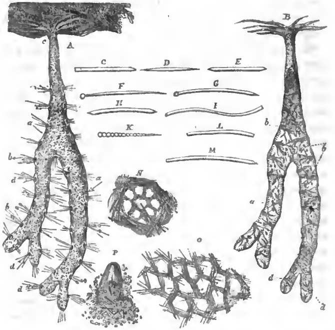
coloured, tuberculated animalcule exhibits in its interior numerous smaller, round, spotted, and similarly formed beings moving to and fro, as seen at A, and the entire volvox does not change or vary its external form while it is seen swimming about slowly with the enclosed young. When the exterior capsule, or the parent animalcule bursts, as is represented at B, and the young have escaped, we observe its fragments to retain their original form with some degree of elasticity when they are tossed about in the fluid by the motions of other animalcules. We see the same transparent elastic integument giving form and support to the *volvox morum*, (Fig. 1. C.) which contains a much greater number of young in its interior, and the same is seen also enveloping the separate globules which compose the body of the *gonium pectorale*. (Fig. 1. D.)

But the most distinct form of the skeleton met with in this class, is that which envelopes the body as a sheath, into which the animalcule can withdraw its soft parts when alarmed, and from which it can extend its ciliated anterior portion for the purposes of nourishment, respiration, or progressive motion. This vaginiform, exterior, thin, pellucid, elastic covering is seen in the *vaginicola innata*, common in sea water. This animalcule, formed like a *vorticella*, is seen in Fig. 1. E, extending its ciliated anterior margin from the opening in its sheath, and swimming by the action of its cilia. The same animalcule is represented at Fig. 1. F withdrawn into its transparent covering and fixed by its candiform projecting posterior part. This form of the skeleton seen in the *vaginicola* leads to the vaginiform horny coverings of *campanulariæ*, and other forms of *keratophytes*. There are

about thirty known genera of polygastric animalcules which possess a firm elastic exterior covering, more or less enveloping the body, and analogous to the more solid skeletons of higher classes.

II. *Poriphera.*—The skeleton of poripherous animals consists of separate minute, earthy, crystalline spicula, connected together by a condensed, elastic, cellular substance; or of tubular elastic filaments of a horny consistence. These hard parts are developed internally throughout the whole cellular tissue of the body, and are often protruded externally through the surface, to protect the pores, or the large vents. The earthy spicula in most of these animals are silicious, in many they are calcareous, and, like the horny filaments of other species, they appear to be tubular like many natural crystals, and to have no aperture leading into their internal cavity. The spicula are generally united into fasciculi by an enveloping glutinous, or condensed cellular substance, and by the junction of these fasciculi in various modes, fibres are formed which traverse every part of the body, forming the boundaries of canals and orifices, and giving form and support to the whole of the gelatinous or soft cellular substance of the animal. The forms of these hard parts are different in every distinct species of these animals, and they are constant in the same, so that they present useful characters for the distinction of species in this polymorphous class. They are formed from materials due to the vital energies of the animal, and they form normal and necessary parts of its structure, like the solid skeletons of higher animals. In Fig 2 is represented at A the *haliclona occulata ;* one of these soft animals, with a *silicious* skeleton. It is represented as alive, suspended from a rock by its spreading branched base of attachment (*c*,) the currents of water are seen at (*a*) rushing in through the pores, and issuing from the internal canals by the large orifices or vents at (*b*). The pores, canals, and orifices are seen exposed in the longitudinal section of the same poripherous animal at B. Fibres composed of bundles of spicula generally extend in a longitudinal direction in these animals from the base of attachment to the remotest points of the surface. Smaller transverse fibres of the same composition connect those which are disposed longitudinally, and form the frame-work of the internal

FIG. II.

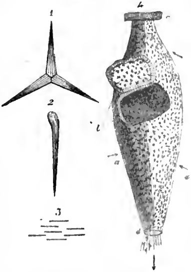


canals. The form of the spicula which belong to several distinct species of poripherous animals are shewn in Fig. 2. at C. D. E. F. G. H. I. K. L. M., each of these forms belonging to a distinct animal, and serving to characterize it. The pores are surrounded with groups of spicula disposed in such a manner as to strengthen and protect the parietes of these minute orifices, and to form a delicate net-work over the whole surface of the body, as shewn on a magnified scale at O, and a single pore is shewn at N still more magnified, with its bounding and defending spicula, and a delicate gelatinous net-work, which protects it from the entrance of small foreign particles floating in the water. The silicious spicula are found in some of these animals while they are yet floating gemmules newly detached from the parent mass, and seeking a suitable place to fix and develope. One of these gemmules is figured at P, highly magnified, and broken to show the spicula already developed in the cellular substance of this minute embryo. Similar silicious spicula occur abundantly

in plants with which these poripherous animals are the most nearly allied.

Several of the animals of this class have the skeleton composed of calcareous spicula which have generally more complex forms than the silicious. They are disposed in the same manner and for the same object through the interior cellular substance of the body. They impart a white colour to the whole body of the animals in which they occur. They do not appear to occur along with silicious spicula in the same animal. The skeleton is generally more loose and friable in the calcareous poriphera, and the connecting glutinous and cellular matter is less abundant. One of these white friable calcareous poriphera, the *leuconia compressa*, very common in our seas, is represented in Fig. 3 at 4 in form of a compressed lengthened sac suspended by its peduncle from any submarine substance (*c*).

FIG. III.

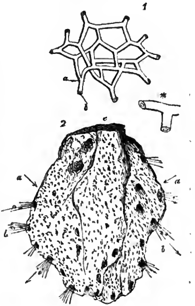


The pores through which the currents are conveyed into this sack are seen all over the exterior surface, as at *a a* ; the canals are contained within the thickness of its parietes, and the large vents or fecal orifices here open into the interior, as seen where it is broken open at *b*. The sac being open only at its pendent extremity *d*, the whole of the inhaled water rushes incessantly out through that general aperture. In the silicious skeletons of this class we find but one form of spiculum for each animal ; but in the calcareous generally two, and one of these has a triradiate form, as represented in Fig. 3 at 1. This triradiate form of calcareous spiculum is accompanied by one of some other form, as by that clavate form of spiculum belonging to the *leuconia compressa*, shewn in Fig. 3 at 2 ; the small spicula in Fig. 3 at 3, found in the same animal ap-

pear to be only fragments of triradiate spicula. The triradiate spicula chiefly bound the pores, canals, and orifices, while the curved ends of the clavate spicula hang over the exterior entrance of the pores to protect them. The calcareous spicula do not appear to occur in any of these animals along with silicious forms, and the true horny tubular filaments appear also to occur alone in the more tropical species, without either silicious or calcareous spicula. The calcareous forms of these animals appear to be much more rare, and generally much smaller than the silicious or the horny species.

In the horny species of poriphera the skeleton consists of thin elastic tubular translucent filaments united together and distributed around the pores, canals, and vents. These horny, tough, flexible threads have a close analogy in their mode of distribution through the whole interior of the body to the tough connecting matter of the spicula in the earthy species, and they give form and support to the whole fabric. Sometimes the internal canal which extends through these tubular horny filaments is filled with an opaque matter which gives a greater friability to the threads; but most frequently they contain only a transparent colourless fluid, as we see in the fibres of the common officinal sponge, which is a poripherous animal belonging to this horny group. The skeleton of all the poripherous animals is so soft and flexible in the living state, that none of the lengthened forms appear to be capable of growing in an upright position from their base of attachment. They hang down from the under surface of submarine bodies, as represented in these figures. A specimen of the common officinal sponge with a horny fibrous skeleton, is repre-

FIG. IV.

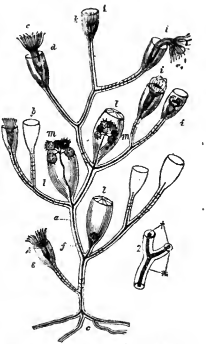


sented in fig. 4 at 2, as alive and cut from its point of attachment, *c*. The circular minute pores by which the streams of water enter the internal tortuous canals are seen all over the surface, as at *a a*, and the large vents by which the currents issue from the body are seen on the most prominent parts, as at *bb*. The manner in which the horny filaments are united to each other throughout the whole mass of the body is seen at fig. 4, 1, where the broken ends of the fibres show their tubular character, and this is still more magnified at fig. 4.* The meshes formed by these horny fibres, though apparently without order or regularity when the soft parts are removed, have the closest relation to the pores and the tortuous canals which wind through every part of the body. Now we see in these simple skeletons of poripherous animals, as in many vegetables still more remote from human organization, that nature begins the formation of an internal framework for the support and protection of the soft parts, by the deposition of detached earthy spicula throughout the cellular substance of the body, as we see in the human embryo the deposition of minute spicula of phosphate of lime in various parts of the soft gelatinous bones begins the consolidation of the skeleton. The abundance of silicious needles in the skeletons of the lowest poriphera assists in their conversion into flint, when their remains have been exposed for ages in chalk or other strata traversed by silicifying percolations.

III. *Polypiphera.*—The skeletons of zoophytes present a great variety of forms and characters, being branched or globular, or filiform, free or fixed, solid, massive, and calcareous, or soft, flexible, and horny, external or internal. The animals of this class obtaining their food by polypi, or highly organized sacs developed from the fleshy substance of the body, we generally find the skeletons, whether external or internal, to present cavities or cells for the reception and protection of these delicate organs; and the various forms of these cells constitute a principal distinction among the skeletons of this class. The simplest forms of the skeleton are presented by the horny zoophytes, or keratophytes, where it sometimes consists of tough, soft, flexible filaments which surround the cells of the polypi throughout the whole mass of the body, as in the *alcyonium* and *lobularia*. These form a transition from the horny species of poriphera to

the more distinct forms of keratophytes. In the horny species of zoophytes the skeleton sometimes forms a tubular external sheath enveloping the fleshy substance throughout all the ramifications of the body, as in all the *sertulariæ*, *plumulariæ*, *antennulariæ*, and many other soft, flexible, and ramified forms. The horny skeleton is sometimes formed by the deposition of successive layers within the fleshy substance of the animal, as in the *gorgonia* and *antipathes*.

FIG. V.



We have an example of an external, tubular, horny skeleton in the common *campanularia dichotoma*, Fig. 5, where we observe it enveloping as a sheath the fleshy substance which occupies the centre of all the divisions of the root, the stem, and the branches. The exterior horny sheath which is exuded upon the surface of the flesh is seen at *a*, and this sheath expands at the extremities of all the branches to form cells, *b*, for the lodgment of polypi *e*, *i*. The base of attachment, spread out and ramified like a root, exhibits the same fleshy interior, and the horny covering extended over all its divisions at *c*. A magnified view of a small portion of a branch is represented at Fig. 5. 2, which shows the fleshy granular or cellular substance † in the centre, surrounded by the tough, elastic, amber coloured skeleton exuded upon its surface *. In the axillæ of many of the branches we observe large vesicles, *l l*, for the protection and development of the embryo. These vesicles in the vaginiform keratophytes are composed of the same firm pellucid substance as the rest of the skeleton; and from the constancy of their forms in the same animal, and their differ-

ences according to the species, they afford useful characters for the distinction of these animals. They are deciduous parts of the skeleton as they fall off after the matured gemmules have escaped from their interior. These gemmules are seen in little ciliated capsules at *m m*, and the polypi are seen in the same figure extended in various attitudes from the cells, in search of animalcules as food. The skeleton of these vaginiform zoophytes often presents a jointed appearance on the stem or branches, as seen in the *campanularia* at *f*; these consist of circular indentations of the surface which do not pass through the interior of the body where they would interrupt the circulation of the nutritious fluid which passes through the fleshy substance in all parts of the body. They allow of a certain degree of flexibility at the most suitable parts of the skeleton, and in some of the horny *cellariæ* they are connected with the deciduous character of the branches. In the *gorgonia*, and some other cortical zoophytes, there is an exterior fleshy substance in the living state which covers all parts of the horny skeleton. This fleshy exterior crust is indeed the animal, which forms by the deposition of successive layers the whole of the flexible branched, horny, and solid internal skeleton. If we make a transverse section of a thick portion of the *gorgonia*, or *antipathes*, we can easily perceive the concentric layers of which it is composed; and by peeling off the cortical fleshy mass from the exterior, and placing this living flesh in the sea, we find it to secret a new internal horny axis for itself. The polypi, which are always and necessarily continuations of the fleshy substance of zoophytes, are developed from this thick fleshy crust in the cortical kinds, and hence we do not see any appearance of cells on the central horny axis in these animals, after the flesh has been removed.

In the calcareous zoophytes the solid mass forming the skeleton is composed chiefly of the carbonate of lime, with a little of the phosphate, and the same condensed glutinous matter which forms the entire skeleton in the keratophytes, is diffused through the whole of the calcareous mass in the more solid lithophytes, where it serves to aglutinate the earthy particles, and to give solidity and tenacity to the entire mass. The calcareous skeletons of lithophytes are for the most part internal, massive, and consisting of a single piece. In madrepores, and many similar forms, the thin

fleshy crust penetrates to a considerable extent the loose, porous surface of the calcareous mass, from which it is capable of receiving some protection, and consequently we perceive distinct indications of the positions of the polypi on the surface of the skeleton in these animals. These cells, for the protection of the polypi, have generally a radiated lamellar structure, and vary remarkably in their size and also in their form in different lithophytes. They are very minute in the *porites*, larger in the *madrepores*, still larger in the *caryophylliæ*, and the *fungia agariciformis* forms but one enormous cell for the lodgment of a polypus like an actinia.

In some of the lithophytes the fleshy crust, as in the cortical kinds of keratophytes, is of great thickness, and the polypi developed from this fleshy exterior mass leave no indications of their position on the surface of the internal calcareous axis. This is seen in the common red coral, which is a solid internal calcareous skeleton, striated with superficial longitudinal grooves, but presenting no calcareous cells for the polypi, which are protected solely by the fleshy thick covering of which they form parts. In the *agariciæ*, *meandrinæ*, and many others, we observe a laminated general surface of the skeleton for the protection of the fleshy mass, but no distinct cells for the polypi. In the *virgulariæ* the skeleton consists of a straight internal calcareous solid cylindrical pillar, occupying the longitudinal axis of the body, and protruding from the lower part of the animal. In the *pennatulæ* the internal calcareous axis is soft and flexible at its extremities, from the abundant proportion of glutinous matter in its composition, and to allow of the necessary contractions and extensions of the animal's body in a longitudinal direction. In the *isis* the internal solid calcareous skeleton is jointed at regular and short distances throughout the whole body, and there are no external cells for the polypi, which are entirely confined to the thick fleshy crust which covers the entire animal in the living state. The joints here consist of the same glutinous tough matter which pervades the whole calcareous axis, and are only uncalcified portions of the general solid axis. They are formed by concentric layers, like the calcified solid portions of the skeleton, and they allow of considerable flexion in the branches and stem of this delicate ramified, and highly organized animal.

As in most other classes of invertebrata, we find many zoophytes which are destitute of an external or internal skeleton, as the common fresh water polype, or *hydra*. Besides the solid internal skeleton in the corticiferous zoophytes we commonly find in the fleshy crust itself minute calcareous spicula. These small spicula compose the hard crust which is seen covering the horny axis of the *gorgonia*, as it is commonly preserved dried in cabinets; and in their occurring thus spread through the general fleshy mass in *gorgoniæ*, *lobulariæ*, and many other zoophytes we observe a lingering analogy with the spicular form of the skeleton in the class of poripherous animals, especially in the calcareous group. The skeleton in the keratophytes is exuded from the fleshy substance in a soft and semi-fluid state, and quickly hardens after its separation from the living parts upon which it is moulded.

As the skeletons of zoophytes are not permeated by vessels, or organized as it is termed, their materials do not expand by growth, but encrease in dimensions by the mechanical addition of new matter. Hence in the vaginiform keratophytes, as *plumulariæ* and *campanulariæ*, we find the base or lower part of the stem, which was formed in the younger state of the animal, to be smaller than the upper part of the stem, which was formed of larger dimensions when the animal, or the contained fleshy substance, had encreased in bulk and development. The large globular masses of *meandrinæ*, *astrææ*, and similar solid lithophytes encrease in bulk by the constant addition of new superficial layers of calcareous matter upon the same primitive plan by the polypherous fleshy covering of the mass. From the origin, and the mode of growth of these calcareous masses, it is obvious that when torn from their primitive seat, they may re-attach themselves, or continue to grow, by the deposition or exudation of new matter, as long as the secreting fleshy crust retains its vitality. These extra-vascular skeletons appear to be very little modified by the contact of the living fleshy parts after they have been once deposited in a soft state, portion by portion, and fully consolidated by the hardening of the glutinous matter in the keratophytes, or by the deposition of earthy matter in the more solid lithophytes.

It is by the contact of living membranes, in the form of capillary vessels, containing fluids, that the decayed earthy

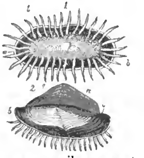
particles of organized skeletons are removed, and have new particles exuded in their place. There are some skeletons of this class which retain an intermediate degree of consolidation between the solid lithophytes and the horny flexible keratophytes, as we see in the *flustræ* and calcareous *cellariæ*, where the proportion of earthy matter is very small compared with the quantity of tough glutinous substance in their flexible skeletons, and we observe them to be thin, soft, transparent, and gelatinous all around their free and growing margins. When these skeletons, whether horny or calcareous, have once been consolidated, they are, like the shells of articulata and mollusca, or like the antlers of the deer, no longer susceptible of growth, and they enlarge or extend by the successive additions of new matter, or of new parts. The carbonate of lime is the common consolidating earth of zoophytes, as silica is that of poriphera; and these are two of the most abundant materials of the mineral kingdom. By the abundance of these calcareous lithophytes on the shallow shores of the tropical seas, they prepare a rich soil for new islands and continents to be raised by volcanic action from the deep, while they at the same time tend to purify the mass of the ocean for the maintenance of higher animals by thus precipitating, in an insoluble state, the corrosive materials conveyed incessantly into its bed by rivers that wash the surface of continents. The deep purple colours of the *corrallium*, the *tubipora*, the *corallina*, and many others, the azure blue of the *pocillopora*, the bright yellow of the *melitæa*, and all the other lively colours seen in these calcareous skeletons are removed by the action of heat, and do not appear to depend on any peculiar mineral ingredient; and we observe the same animal nature of the colouring matter in the shells of articulata and mollusca, and in the coloured bones of many vertebrated animals.

These skeletons of zoophytes are not exudations from the surface of polypi; the cell always precedes the existence of the polypus which is developed within it. They are developed from the gelatinous substance of the reproductive gemmules before any polypi begin to be formed, and they continue to be developed and extended by the fleshy mass of the zoophyte whether polypi are developed in the cells or not. There is but one life, and one plan of development

in the whole mass; and these depend not on the polypi which are but secondary, and often deciduous parts, but on the general fleshy substance of the body.

IV. *Acalepha.*—Although there are no solid skeletons in any of the soft, gelatinous, free, and floating animals of this class, we generally perceive some firmer cartilaginous portions of the body which afford support to the organs of progressive motion or of prehension. There are crescentic cartilaginous laminæ around the inferior central part of the body in the medusæ which give support to the contracting fleshy overhanging mantle, and to the absorbent tubes prolonged from that part. There are firm superficial longitudinal bands in most of the ciliograde acalepha for the support of those minute vibratile fins by the motions of which they are carried through the sea. From the feebleness of their muscular system, and from their swimming habits, it is obvious that the acalepha can only support the lightest forms of the skeleton.

FIG. VI.



In the *velella limbosa*, Fig. 6, which floats on the surface of the sea there is a thin flexible perpendicular crest, (Fig. 6. 2. *a*,) which is covered with a thin layer of the deep blue coloured mantle, and which rests obliquely on a horizontal stronger transparent flexible plate, (Fig. 6, 2 *b*.) The thin perpendicular crest, which rises above the water and serves as a sail, appears to be composed of the same condensed glutinous or horny substance which composes the skeletons of the keratophytes. The horizontal plate is thicker, concave below, marked with concentric lines of growth, and gives support to the deep blue mantle above, to the delicate marginal tentacula, (seen at *b b*, in both views of the velella,) to the numerous tubular suckers, and to the stomach placed beneath this concave horizontal plate.

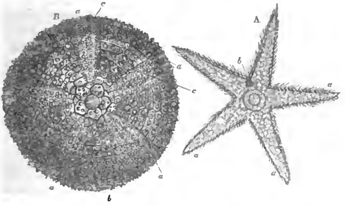
The *porpita*, which is another of these floating *acalepha*, presents a similar thin plate, to this horizontal lamina of the velella, for the support of the same parts, but of a round form, of a white colour, and of a porous texture.

These two simple genera of acalepha present examples of the thin, light, and delicate forms of the skeletons which we find in almost all the floating marine invertebrata.

V. *Echinoderma.*—The skeletons of the animals of this class are generally in the form of external crusts or shells, covered with projecting spines. They are composed of the carbonate, mixed with a small but variable proportion of the phosphate of lime, and are hardened by animal matter. The phosphate is always in a small quantity compared with the carbonate of lime, but is more abundant in the solid shells of the echinida than in the softer coriaceous and tuberculated coverings of the stellerida. The skeleton of all these animals consists of numerous detached or separate pieces, which protect the interior viscera, give attachment to the organs of motion, and generally give form to the whole body. The solid pieces which compose the skeleton are for the most part in form of calcareous plates, symmetrical in their shape and in their arrangement, and which present considerable uniformity of plan in their disposition throughout the diversified forms of this class. The body most frequently presents a radiated form in the animals of this class, the parts projecting in a stellular manner from around a longitudinal axis, as is seen in the various crinoid animals fixed by a jointed peduncle and ramified above, and in the various forms of existing stellerida, as the *asterias*, the *ophinra*, the *euryale*, and the *comatula*, which are not fixed by a peduncle; and we can easily observe the same plan of structure in the more concentrated and globular forms of the echinida, as the *scutellæ*, the *clypeasters*, the *spatangi*, and the *echini*.

The radiating portions of these animals are composed of numerous rings or segments, like the trunk and members of articulated animals, and each of these component segments is surrounded by numerous calcareous plates. One of these radiated or stellular forms of echinoderma is seen in the common *asterias aurantiaca*, (Fig. 7. A.) where there are five rays or divisions of the body, the number most frequent in this class. On examining the sides of these rays from above, as the animal is placed in the figure, we observe the ends of large lateral plates (Fig. 7, A. *a a a*) which bound the margins of all the rays. These plates are connected with others which surround chiefly the sides and lower surface

FIG. 7.



of the rays, and form the ambulacral grooves below for the tubular fleshy feet. Besides the tuberculated coriaceous irritable skin covering the upper or dorsal part of each small segment of each ray, we can generally distinguish eight calcareous plates placed transversely on each segment, and surrounding its sides and lower surface. In the sea-star represented in the figure there are eighty of these transverse divisions or segments in each of the five rays of the animal. In all the segments of a single ray there are about seven hundred plates, and about three thousand five hundred calcareous pieces in the segments of the whole animal. The concave lower surface of each ray is perforated by numerous pairs of small oblique holes placed on each side of a longitudinal median line, which are the ambulacral perforations for the tubular fleshy suckers, by which these animals drag themselves along the bottom of the sea, or up the perpendicular sides of rocks. The lateral and dorsal parts of the segments often support fixed or moveable spines which grow like the plates themselves by the successive addition of calcareous layers from the thin fleshy secreting membrane which covers every part of the calcareous skeletons of echinoderma.

On the back of these animals, and a little to one side of the centre, between the commencement of two of the rays, there is a small, round, solid, calcareous body, represented at *b*, in Fig. 7, A. This round calcareous plate is convex

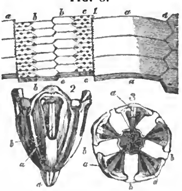
above, and presents an exterior surface marked by numerous tortuous grooves, like the surface of a *meandrina*. In its concave interior surface it protects a small membranous sac, which contains a thick grumous matter chiefly composed of carbonate of lime with a little phosphate, and was supposed by Tiedemann to be the organ which separates from the fluids of the body the calcareous matter of the exterior covering. The arrangement of the plates enveloping the segments is very similar to this in all the other forms of *asterias*, however they may vary in the number of the rays, and in the *ophiuræ* where the rays do not contain prolongations of the digestive and generative organs, and in the other forms of stellerida.

In the more compact forms of the echinida, the skeleton is more solid, contains more phosphate of lime, and the component plates are arranged with more obvious symmetry. The plates are arranged in perpendicular or longitudinal columns extending from around the mouth to the anus, as is seen in the figure of the common *echinus esculentus*, (Fig. 7, B.) which represents the entire shell, as seen from above, and deprived of its exterior spines. Some of these vertical columns are seen to be perforated with the same kind of small round oblique ambulacral holes as in the *asterias*. These perforated ambulacral columns, (Fig. 7, B, *a*, *a*, *a*,) are ten in number, disposed two and two together, so as to form five pairs. The letters *a*, *a*, *a*, point to the middle line of separation between each pair of ambulacral columns. Between these five pairs of small perforated columns are placed alternately five pairs of columns of larger tuberculated plates which are not perforated for the feet. These tuberculated columns in pairs interposed between the successive pairs of ambulacral columns are seen in Fig. 7, B at *b*; and the line of separation between the tuberculated and the ambulacral columns is represented at *c*, *c*. The whole exterior of the shell being covered in the recent state with moveable spines attached to the tubercles we cannot perceive the arrangement of these vertical columns of separate plates till the spines are removed, or the shell is broken and viewed on the inner surface.

A small portion of the shell of the *echinus esculentus*, magnified and viewed from the inner surface, where the ar-

rangement of the plates is best seen, is represented in Fig. 8, 1, where *a*, *a*, represents the smooth inner surface of the large tuberculated plates, and *b*, *b*, the inner surface of the perforated ambulacral plates. There are ten vertical columns of tubercular and ten of ambulacral plates which vary in the number of pieces they contain, according to the age of the animal. The larger plates are the tubercular *a*, *a*, which have a pentagonal form, and are lengthened transversely. There are about thirty-two of these tubercular plates in the adult animal, in each of the vertical columns, making three hundred and twenty plates of this form in the ten columns. The columns of tubercular plates meet each other by obtuse, salient and re-entrant angles, as seen at *d* in Fig. 8, 1, forming thus a regular zig-zag line by the contiguous columns of these plates, and the shell is much strengthened by the alternate manner in which the sutures are arranged. The ambulacral plates form also five pairs of columns (Fig. 8, 1, *b*, *b*,) each column containing about eighty pieces. The tubercular columns are united to the ambulacral by minutely serrated edges, and the ambulacral columns are united to each other by the same form of zig-zag suture as that between the tubercular plates. The ambulacral plates however (Fig. 8, 1, *b*, *b*,) appear to have their perforated portions detached by small sutures which traverse all the foramina, (Fig. 8, 1, *c*, *c*.) There are thus ten columns of these minute perforated pieces, each column having one hundred and sixty pieces. The contiguous portions of the ambulacral pieces, (Fig. 8, 1, *b*, *b*,) are covered externally with tubercles like the larger tuberculated pieces. (Fig. 8, 1, *a*, *a*.) When we examine the fractured edges of these shells, we observe the colouring matter of the surface to pass under the superficial tubercles, which appear not to be continuous portions of the plates to which they adhere by a broad spreading circular base. The tubercles are few on the small terminal plates, but numerous on the large pieces in the middle of

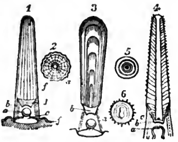
FIG. 8.



the columns. There are at an average at least ten tubercles for each tubercular plate, and three tubercles for each of the tuberculated portions (Fig. 8, 1, *b*, *b*,) of the ambulacral plates. Every tubercle of the shell supports an external, moveable, calcareous spine; so that there are more than ten thousand pieces in the shell of the *echinus esculentus*, without counting the complicated dental apparatus of the mouth, or the respiratory and ovarial plates, or the very minute calcareous pieces disposed irregularly on the coriaceous membrane around the oral and the anal orifices. There are five large heart-shaped plates disposed around the anal aperture, as seen in the central part of Fig. 7. B, each of which is perforated by a large round hole for the termination of one of the five oviducts. Between the tapering exterior ends of these five ovarial plates there are five smaller heart-shaped plates, each of which is likewise perforated with a small round hole. Around the lower orifice of the shell the last pairs of tubercular plates send in arched processes which meet each other over the ambulacral plates, and give a fixed and extensive surface for the muscles of the dental apparatus. The five teeth and their alveoli are represented as seen laterally at Fig. 8, 2, and as seen from above at Fig. 8. 3. There are five teeth, (Fig. 8, 2, *a*, *a*,) of a compact and dense texture where they project downwards from the alveoli, and of a loose and fibrous structure at their upper part, where they are enclosed in their complicated alveoli. The alveoli (Fig. 8, 2, *b*, *b*,) are long, slightly curved, hollow, tapering from above downwards, moveable individually and collectively, and held in connection by several distinct moveable pieces, (Fig. 8, 3, *b*, *b*,) at their proximal extremities. This dental apparatus, which exists also in the *cidaris*, is wanting in the *spatangus*, and several other genera.

The exterior surface of the shell is covered, in the echinida, with solid calcareous spines, which rest and move upon the round tubercles. These spines are very large in the *cidaris*, where the shell is small; and they are small in the *echinus* and *spatangus* where the shell is large. They grow like the other parts of the shell, by successive deposition from the enveloping fleshy substance. Sections of these spines, and of the tubercles on which they rest, are represented in Fig. 9, where 1, represents the entire spine of the common echinus esculentus, and 2, a

FIG. 9.



transverse section of the same spine. In Fig. 9, 1, *a*, is the round tubercle on which the spine moves; *b* represents the muscular fibres which descend from the margin of the spine to the circumference of the base of the tubercle; *c*, *d*, is a distinct part of the base of the spine formed within the capsule of the joint; and *f*, *f* represents the soft secreting fleshy layer which envelopes the whole exterior of the skeleton. The concentric layers by which this spine is enlarged are seen in the transverse section, Fig. 9, 2. These superimposed layers of growth are represented in the longitudinal section of a large spine of *echinus mammillatus* (Fig. 9, 3,) where *a* represents the muscular fibres by which it is moved and attached, and *b* is the compact portion of the spine formed within the capsule of the joint.

In some of these external spines of echinida the growth appears to be effected by the addition of calcareous matter only to the proximal extremity, or fixed ends of the spines. The lines of growth do not then converge and meet in the longitudinal sections, but diverge and terminate at the sides of the spines. This structure is seen in the spines of the *cidaris pistillaris*, represented in Fig. 9, 4, 5, 6, where *a* is the tubercle with a cavity at its summit, as we commonly find in the animals of this genus; *b* is the concave base of the spine, with a cavity in its centre, as in the tubercle on which it moves. The compact portion of the spine formed within the capsule is seen occupying the middle of its whole extent, and the successive layers of growth are observed extending from this central portion to the sides along the whole spine. A view of the base of this spine is given at Fig. 9, 5, and a transverse section of its middle is represented at Fig. 9, 6, where we see the concentric layers of growth around the middle compact portion. Interspersed among the spines of the *echini* we find small, fleshy, cylindrical organs which terminate in three moveable calcareous spines. Many of the echinoderma have no external skeleton, and are covered only with a coriaceous irritable skin.

In the *holothuriæ*, which are animals of this kind, there are only five pairs of small calcareous pieces disposed around the mouth like the dental apparatus of the *echini*. These pieces give support to the ramified tentacula, and afford a firm attachment to the strong longitudinal muscular bands which encompass the body.

THIRD SECTION.

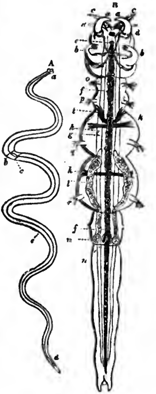
On the Organs of Support in the Diplo-neurose, or Articulated Classes.

The animals of this great division have the trunk of the body for the most part long and cylindrical, divided transversely into segments, and provided with numerous pairs of organs of motion symmetrically disposed along the sides. From their activity, their skeleton is generally in form of a light, thin, exterior, enveloping, condensed integument, to the inner surface of which the muscles are attached through the medium of the cutis, and which is periodically cast and renewed, to allow of the growth and increase of the enclosed soft parts. The articulated appearance of the skeletons in these animals is generally proportioned to the density of its texture. Where the whole skeleton is soft and flexible, there are few or no traces of articulations, and where its texture is dense and unyielding, the articulations are most distinct and complete; hence in the helmithoid classes, and in the young state of the entomoid animals, the articulated appearance of the skeleton is less distinct than in the adult forms of the articulated animals with articulated members. The tubular form of the hard enveloping parts of the articulated animals, and their unorganized nature require them to be exuviable, and as they are thus the result of a single effort of formation, they are always thin and light coverings. They are not reinforced by successive deposits added to the surface, through the whole of life, as in the molluscous classes, and consequently we find but little of that softer material, the carbonate of lime, employed in their consolidation. The more dense material of the phosphate of lime

is almost always substituted for that earth, as we see also in the vertebrated classes. In some of the more solid and massive coverings, however, of these animals we meet with the carbonate of lime, as in the *serpulæ*, the *cirrhopods*, and the *crustacea*.

VI. *Entozoa.*—The intestinal worms have for the most part a tough exterior, transparent and almost hermogenous covering spread over their whole body, to which they owe their peculiar stiffness and elasticity, and to the inner surface of which their cutaneous muscles are attached. This part is composed of the true skin, and that epidermic covering which becomes consolidated into a dense exterior skeleton in higher classes. It is here soft and elastic, to allow them with more ease and safety to move through the tough and constantly moving parts of the living animals in which they reside. The long cylindrical bodies of these parasitic worms would be impeded in their motions by any hard, inflexible shelly covering, which likewise could not be cast off and renewed in such a medium; hence their smooth, glistening, and unctuous covering has only that degree of density and toughness, which is adapted to protect them from tearing and compression during the movements of the living parts around them. This transparent elastic tunic is especially thick and firm in the long cylindrical, filiform, or trematoid entozoa, as the *filaria*, the *strongylus*, the *echinorhynchus*, and the *ascaris*. In the *ascaris lumbricoides*, which is represented in Fig. 10,A, this covering is thick and tough; but so transparent as to allow the white layers of muscular fibres to be perceived through it. The three moveable oral lobes are

FIG. 10.



seen at *a*, the abdominal nerves are seen as a single line running along the middle of the ventral surface, and separating to encompass the vulva at *b*, and the anal opening is seen near the posterior termination of the body at *d*. In the jointed *tæniæ* and *bothriocephali*, this covering is soft and thin, these being almost aggregates of simpler animals, and it is still more thin and dilatible in the *hydatids* and *cænuri*. This exterior covering often presents an irregular transversely-corrugated appearance during the contracted state of the long filiform antozoa, which arises from the still irregular attachment of the interior interrupted longitudinal muscular fibres; and these irregular transverse corrugations present us with the first condition of those joints and rings which become so regular and distinct in higher articulated classes. This exterior soft covering of the entozoa presents us also with the lowest form of that cyclo-vertebral element, which forms by its consolidation and repetition, a series of calcified rings or segments around the exterior of the trunk in higher entomoid articulata, and the solid bodies of the vertebræ in the red-blooded classes.

In most of the inferior orders of entozoa there are numerrous dense conical recurved hollow, and sharp pointed spines which are sometimes disposed as teeth around the mouth, and sometimes are found covering a great portion of the anterior part of the body, giving it the appearance of a file to abrade the surface on which they are to feed, or through which they have to force their way. These hollow spines are thus organs of progressive motion, like the cirrhi and setæ of annelides. They are strongest and most numerous in the acanthocephalous species, where they cover the whole of the retractile proboscis, and sometimes, as in the *echinorhynchus hystrix*, nearly the whole of the anterior surface of the body. There is thus a transition from these teeth-like organs in the interior of the mouth, and those covering the surface of the body in these soft worms which move through a fleshy resisting medium everywhere in contact with them, to the lateral spines of the annelides which can be moved with more freedom and more precision through a thin aquatic or aerial medium, as in the aquatic annelides and the earth-worms.

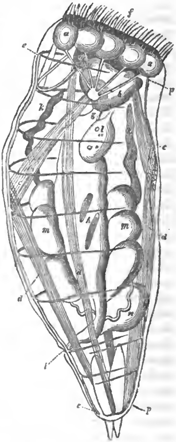
The exterior covering is more dense in its texture, and consequently more articulated in its appearance in those

parasitic worms, which are found attached to the exterior surface of the gills, the lips, the eyes, and other soft parts of fishes, and which have thence been called *epizoa*. We already find in many of these animals, as in the *lernææ* and *chondrocanthi*, not only the head forming a distinct segment of the body, and the trunk partially divided by transverse depressions, but numerous appendices already developed from the sides of these segments, and some of these appendices, especially on the head, provided with moveable articulation. This dense covering is still so transparent and hermogenous, that we can distinctly perceive through it, the longitudinal muscular fibres which produce the numerous corrugations of the skin, and also the contained viscera. The transition is quite imperceptible from these epizoa, as the *tracheliastes* and the *achtheres* to the fixed parasitic entomostracous crustaceous animals, as the *ergasilus* and the *lamproglena*, where the exterior covering has the same texture and properties, and where the articulated appearance of the trunk and its appendices is nearly in the same simple condition. One of these lowest of the entomoid tribes almost inseparable from the epizoa, the *lamproglena pulchella*, is represented in Fig, 10, B. where we already observe the head and three principal divisions of the thorax distinctly marked, as in insects. We perceive in this little animal, found attached to the gills of the *cyprinus jeses*, two pairs of maxillæ, *a, a, b, b*, formed like curved pointed feet, and two pairs of antennæ *c, c, d, d*, as in higher crustacea. Above the mouth *e*, are seen the two eyes united on the median plain as in higher monoculi, and the intestinal canal *f*, is observed surrounded by the follicles of the liver, and passing straight through the middle of the whole body, as in most parasitic and carniverous articulata. Pairs of feet, *p, q, r*, are seen extending from the sides of the segments, and transverse fasciculi of muscular fibres *i, h, k*. The unimpregnated ovaries *l*, closed above and filled with imperfectly developed ova which afterwards descend to external sacs, open on each side of the last distinct segment by a trilobate orifice *m*. All the external parts of this very minute animal are developed nearly to the same extent, and articulated to as great a degree in the achtheres and several of the higher of the acknowledged epizoa ; so that we have already developed in the lowest of

the helminthoid classes, the rudiments of all those characteristic parts of the complicated skeletons of insects, and of all the higher entomoid articulata.

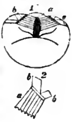
VII. *Rotifera.*—The wheel animalcules are more closely allied to the helminthoid articulata than to any of the inferior radiated classes, especially in their supra and infra-æsophageal ganlia, their abdominal longitudinal nerves, their dorsal vessel for circulation, their lateral maxillæ, their highly developed genetal system, and their muscular activity. Their exterior covering, though generally thin and transparent as crystal, appears to possess considerable firmness from the numerous powerful muscles inserted into it, and from the transverse corrugations it presents when the body is drawn backwards to their fixed caudal extremity. Sometimes it is in form of a sheath enveloping the middle of the body, and open both before and behind, to allow the head and tail to be retracted and protected. This firm tough elastic covering of the rotifera has some resemblance in its hermogenous texture to that of the entozoa, and probably is persistent and enlarges with the body. There are no earthy deposits formed in any part of the body of these minute and active animals. The densest parts of their body appear to be the two jaws which move transversely by powerful muscles, and are generally provided with numerous sharp teeth. One of these wheel-animalcules, termed *hydatina senta*, common in our ponds of fresh

FIG. 11.



water, is represented in Fig. 11, where we perceive seventeen muscular lobes, *a, a,* for the movement of the vibratile cilia, *f*, disposed around the mouth. The muscular apparatus *b*, of the maxillæ and the mouth are retracted by longitudinal muscles *c*, which pass obliquely backwards, and the whole body is forcibly retracted towards the fixed caudal extremity by several longitudinal bands *d*, of muscular fibres which extend the whole length of the body. The large central or supra-æsophageal ganglion *o*, is accompanied by four other ganglia, disposed around the œsophagus, and abdominal nervous filaments *p*, are perceptible, extending longitudinally on the inferior surface, as in other articulated classes. The muscular apparatus of the jaws may almost be regarded as analogous to the muscular stomach armed with teeth common in crustacea. The narrow part of the intestine considered as the œsophagus *g*, leads to a long and capacious digestive cavity, which in many of the genera of rotifera developes numerous cæcal appendices, like the biliary follicles of annelides. In this capacious intestine, extending from *g*, considered as the œsophagus to near the anus, *i*, on the dorsal part, we observe small animalcules, *naviculæ*, *h*, which have been swallowed entire. The longitudinal dorsal vessel *e*, more like an abdominal nerve, as in other articulata, follows the median line, and gives off numerous lateral branches in its course. Two glandular sacs *l*, appear to pour their secretions into the muscular cavity of the mouth, as the liver into the muscular stomach of crustacea, or the salivary sacs into the œsophagus of mollusca. The two ovaria *m*, form large lobed organs extending upwards on each side of the intestine, and open by one orifice into the cloaca, behind the rectum *i*, and two long narrow glandular sacs *k, k*, considered as testes, pour their secretions into a large membranous vesicle *n*, situate behind the cloaca. The jaws of this animal are represented apart from the body, along with their enveloping muscular apparatus, in Fig. 12, where 1, *a*, shows the serrated edges of the numerous teeth on each side of the opening of the mouth, 1, *b*, the muscular apparatus of the jaws, and 1, *c*, the general muscular sac of the mouth. One of the jaws is represented at 2, Fig. 12, separated from the muscular sac

FIG. 12.

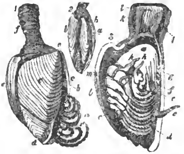


of the mouth, where the parallel teeth composing the jaw, so variable in number in the rotiferous animals, are seen at *a*, and the insertions of the muscles at *b*. Sometimes only a single tooth on each side is seen to compose the jaws, and they have been observed to vary in the number of component teeth in the jaws of different animals from one to six in each jaw. Thus their most solid parts relate solely to digestion, and the lightness of their exterior covering corresponds with the constant and rapid movements of these rotifera through their watery element.

VIII. *Cirrhopoda.*—The cirrhopods, like the entomostracous crustacea, are articulated animals enclosed in shells like those of mollusca, so that they present both forms of the skeleton. They have six pairs of curled jointed members extending from each side of the body, from which this class has received its name. Each pair arises from a short thick fleshy peduncle, and the peduncle or haunch of the anterior shortest pair, those on each side of the mouth, support a pair of short, pyramidal, laminated, branchiæ, like those attached to the haunches of the legs in most of the crustacea. The feet are covered externally with a transparent, firm, elastic integument, are regularly and closely jointed to their finest extremity, and are furnished with minute jointed cirrhi disposed along each side of their inner concave surface. The trunk of the body between the feet is also partially jointed; it presents the usual nervous columns and ganglia disposed along the ventral surface, as in other articulated classes; and, as in them, the intestine passes straight from the mouth to the anus, which opens into a long thin flexible conical tube. The mouth of these animals is furnished with an upper and a lower lip, with a pair of mandibles and a pair of maxillæ. The maxillæ are furnished with small fleshy palpi, and the lower lip is formed by the union of the exterior maxillæ. The cirrhopods are almost always inclosed in multivalve shells secreted from the outer surface of a fleshy, thin enveloping mantle, and which are attached to submarine bodies either directly by their base, or by means of a fleshy tubular peduncle. These exterior shells are generally thin, laminated, dense, composed of carbonate of lime with animal matter, and grow by the successive addition of layers to their inner surface. The

testaceous coverings are most developed in the *balani*, where the articulated members of the contained animal are least, and these exterior shells are least in the *anatifæ*, and other pedunculated genera where the feet are largest. The acorn-shells, or balani, form a hollow cone composed of six pyramidal pieces, ribbed longitudinally with tubular cavities, and overlopping each other in an imbricated manner by their thin margins. These strong pyramidal plates, striated internally, both transversely and longitudinally, rest their broad bases on the margin of a circular fixed calcareous disk, striated in a radiated manner with small hollow tubes which open into those of the pyramidal plates. Between the superior separated apices of these larger plates, are interposed six smaller pyramidal pieces with their points directed downwards, so that their bases complete the upper free and smaller margin of this truncated hollow cone. The smaller inverted plates appear to be anchylosed to the larger inferior pieces. Within this fixed cone, which has the means of continued increase by its subdivision into numerous pieces, there are four moveable triangular plates, two larger and two smaller, which form an operculum to open and close at the will of the animal. In the anatifa or *pentalasmis*, represented in Fig. 13, we have an example of the ordinary form of the skeleton in the barnacles, or lepades, suspended by a fleshy peduncle. The shells here are thin and diaphanous, and by their striated outer surface, they mark the limits of the successive layers of growth, and the opposite directions in which these layers are extended in the two lateral pieces of the shell. Fig. 13,1,represents the entire shell with the jointed members of the animal projecting from the aperture, and a portion of the contracted peduncle. The jointed members *a*, with their jointed

FIG. 13.



cilia are here very long, and are seen partially extended from the open anterior aperture *b*, of the shell. The peduncle *f*, is composed of a tough exterior coriaceous tunic, and

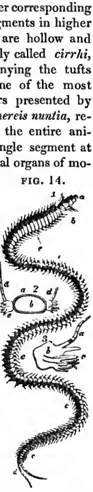
an inner muscular coat, so that it is capable of rapidly contracting when alarmed. The dorsal shell *e*, is the only piece placed on the median plain, and grows by layers added to its inner surface and increasing successively from the proximal to the distal extremity. The larger lateral pieces, *c, c*, to which the animal is fixed by a strong transverse muscle of attachment, as in bivalved mollusca, grow likewise by layers extended from the whole of the distal margin, the centre of ossification being at the proximal point. The two distal smaller opercular pieces *d*, grow from their distal towards their proximal ends. From their greater extent of motion by means of their long fleshy peduncle, these lepades do not require to possess external shells so strong as the fixed sessile balani. A dorsal view of the same shell on a more reduced scale is given in Fig. 13, 2, which represents the direction of the successive layers of growth of the dorsal plate *a*, which is analogous to the whole complex cone of the balani, the four lateral moveable pieces representing the four valvular small pieces in the sessile species. In Fig. 13, 3, the tubular peduncle is divided to show its outer coriaceous covering *k*, and the inner muscular coat *l*, with the interposed skin *i*, and the right side of the shell is removed to show the inverted and curved position of the animal in its cavity. In some of the pedunculated cirrhopods, as the *pollicipes*, there are several small supplementary calcareous pieces placed at the junction of the peduncle with the base of the shell, and some, as the *cineras*, have only a cartilagenous or membranous covering unconsolidated by calcareous pieces. The anterior part of the body (Fig. 13, 3, *a*,) of this enclosed animal, as in most other articulata, has less of the articulated appearance, less distinct segments than the posterior portion of the trunk, and the skin of that anterior part is here thin and membranous. The abdominal, or posterior portion of the body (Fig. 13, 3, *b, c*,) is that tapering articulated, and free part, from the sides of which the articulated cirrhated and pedunculated members project. The muscles by which the anterior bulbous part of the trunk is attached to the valves of the shell are seen at *g*, and the strong adductor muscle passing across from the right to the left valve, and by which they are firmly closed when the animal is alarmed, is seen at *f*. The six thick muscular peduncles

for supporting and moving the six pairs of long articulated members on each side are seen at *b*, *c*, and the branchiæ attached to the anterior or smallest pair of these haunches are seen at *h*, *h*. The membranous conical long tube continued from the anus is seen extending from the shell at *e*. These articulated organs of the cirrhopods attached to the sides of the abdominal portion of the trunk are in constant movement during life, extending and retracting, like the branchial organs of the post-abdomen in the branchiopodous crustacea.

IX. *Annelida.*—The red-blooded worms lead us a stage higher in the development of the articulated skeleton, and especially in the organs of locomotion. Some, as the *pleione* and the *halithea*, have the exterior covering of the body still so soft and membranous, as scarcely to present an articulated appearance. Some, as the *leech*, have only the trunk of the body developed, and from the want of lateral setæ and cirrhi for progressive motion, have the segments surrounding the body very short and numerous, and thereby possess great flexibility of the trunk. In the earth-worm, the segments of the trunk are larger and firmer, and each ring is provided with eight very small curved, conical, hollow, sharp pointed spines or setæ, which are disposed on the sides of the segments in two upper and two lower pairs. These setæ are surrounded each with a muscular sheath for their advancement and retraction, and they serve as organs of locomotion. In some annelides the setæ are hooked at their points, in others they are compressed, or spatulate, and in others subulate. In the simplest forms of annelides we sometimes find, as in the *nais*, but one long filament or seta developed from each side of each segment, which however still materially assists them in moving over a solid surface, or through narrow passages, or in their serpentine motions through the water. The softness of the skin in most of the annelides compensates for the want of articulated feet, by allowing greater flexibility to the trunk, and the delicate sensibility of the whole skin compensates for the imperfect development of their organs of sense. This delicate and unprotected condition of their outer surface requires many of them to shield their whole body in external solid adventitious tubes, often most artfully constructed, and some, as

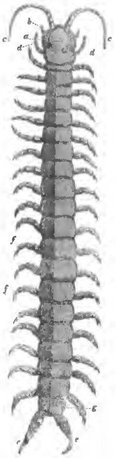
the *serpulæ* exude a calcareous conical tube from the surface of their skin, which enlarges like the conical shell of a gasteropod, by the successive addition of new and wider cones to its interior surface. But the true skeleton of these articulated worms, as in the higher entomoid classes, is their exterior skin and epidermic covering, to which the muscles of locomotion are attached, whether this part be hard or soft. The upper lateral setæ of the annelides appear to be the analogues of the wings of insects, and other corresponding parts extending from the sides of the segments in higher classes. When the setæ of the annelides are hollow and jointed, or sub-articulate, they are commonly called *cirrhi*, as we see in the long jointed cirrhi accompanying the tufts of setæ on the sides of the nereides. One of the most articulated forms of the body and members presented by this class is seen in the sea-centiped, the *nereis nuntia*, represented in Fig. 14, where a dorsal view of the entire animal is given at 1, a transverse section of a single segment at 2, and a magnified view of one of the lateral organs of motion at 3. We already find in this worm the head (Fig. 14. 1, *a*, *b*) distinct from the trunk, and consisting of several separate and moveable segments. The head is provided with sharp, curved pointed maxillæ, with serrated inner edges. There are numerous separate small simple eyes, or ocelli, disposed chiefly in transverse rows, and there are several lateral tentacular filaments having the character of antennæ. There is an enlarged anterior part of the trunk (Fig. 14, 1, *b*, *e*,) corresponding with the thorax of insects, and the segments are nearly equally developed from this point to the posterior end of the trunk. All the segments of the head and trunk are still moveable on each other; they are almost equally developed and equally provided with lateral appendices. In the transverse view of one of the segments (Fig. 14, 2,) of this *nereis*, we observe the lateral appendices to consist, on each side, of a long jointed slender tubular cirrhus (Fig. 14, *c*, *d*,) and a fasciculus

FIG. 14.



of shorter setæ placed below. This lateral organ of motion is seen on a more magnified scale in Fig. 14. 3, where *a* represents the jointed cirrhus, and *b*, *c* the tuft of setæ. These segments and their appendices vary much in their degree of consolidation, in some being soft and transparent, and in others opaque dense and covered with pearly or metallic lustre. The tubicolous annelides which form the densest exterior tubes have generally the segments less marked, and covered with a softer skin than those which are found in soft tubes, or are entirely without such protection. We have thus already developed in the annelides, the segments of the body and their jointed tubular appendices for progressive motion, and all the essential parts of the skeleton which present themselves under various forms throughout the entomoid classes.

FIG. 15.



X. *Myriapoda.*—In the myriapods the skeleton is more dense, the articulations are more distinct, and the jointed tubular appendices, for progressive motion, are more developed from the sides of the segments than in the helminthoid classes. Their muscles having firmer points of attachment, act with more energy and effect, and their movements effected in the thinner medium of the air are more lively than those of the helminthoid animals which mostly inhabit a more dense aquatic medium. The segments of the body are here more numerous than in the higher articulated classes, and they are still, as in the annelides, nearly equally developed throughout the whole trunk. In some, as the *iuli*, the segments are calcareous, hard, and cylindrical, and the lateral appendices or feet are short, and for the most part double on each side of each segment. In other myriapods, as the *scolopendra*, represented in Fig. 15, the segments are depressed, coriaceous, composed simply

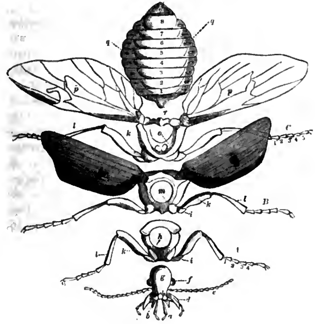
of an upper and a lower arched plate, attached by a softer flexible portion of the skin upon the two sides, and generally each segment presents but one pair of extremities more lengthened than in the *iuli*. The first pair of feet are here in form of simple curved perforated hooks placed at the sides of the mouth, and the succeeding feet along the whole sides of the trunk terminate in a single sharp conical claw less curved, with a very minute opposable spine extending from the interior of each terminal joint. The antennæ (Fig. 15, *c*, *c*) are two in number, as in insects, and for the most part long, filiform, and multi-articulate, and the organs of vision generally consist of numerous simple eyes placed in a group behind the bases of the antennæ.

In the cylindrical vermiform *chilognatha*, the mandibles appear to be still destitute of palpi, whieh are developed on the mandibles of the larger *chilopoda*. The segments of the head, thorax, and abdomen are scarcely yet distinguishable from each other. The stigmata for respiration open on the sides of the alternate rings of the trunk, as if these were equivalent to only a half of the ordinary rings or segments of insects. The two last pairs of feet (Fig 15. *e*, *e*) generally extend backwards in form of a bifid tail: they are for the most part longer than the other feet, and sometimes form foliated expansions at their free extremities, as we likewise often see in the crustacea. The segments of the trunk lie over each other in an imbricated manner at their line of junction, so as to defend the internal soft parts during the bending serpentine motions of the body. These animals do not undergo metamorphoses like insects, nor acquire wings, but the number of their segments varies with their period of growth; and from the density of their external coverings, their unorganized nature, and their enveloping tubular forms, they are exuviable, like the dense skeletons of all the articulated tribes with articulated members.

XI. *Insecta.*—The skeleton of insects, from its superficial position, and from the lightness and density of its materials, is well adapted for intevertebrated animals destined for an aërial life. It is composed, in its densest parts, of a thin epidermic layer, a colouring matter often presenting the most lively hues, and a brilliant metallic lustre, and a thicker internal layer much resembling the woody fibres of plants, but composed of peculiar animal

substances, termed *chitine* and *coccine*, and consolidated by small proportions of the phosphates of lime, magnesia, and iron. As in other entomoid classes, the trunk is surrounded with hollow rings or segments, which on the anterior parts of the body support lateral appendices appropriated to sensation, mastication, or progressive motion; and consequently, on these anterior portions of the body, the segments are more consolidated and more firmly united together than in the flexible and capacious posterior part. There are generally thirteen segments distinguishable in the trunk of insects, of which the anterior forms the *head*, the next three the *thorax*, and the posterior nine the *abdomen*. The annexed diagram from Carus shows the form and position of these parts of the skeleton viewed from behind in the *calosoma sycophanta*, (Fig. 16.) a coleopterous insect. The body of insects generally tapers more or less at both ends, and the terminal segments before and behind are those least developed; those composing the head indeed

FIG. 16.



are so small, indistinct, and anchylosed together, that entomologists are not agreed as to their number, some considering this part as composed of one segment, some of three, and others of seven segments consolidated together. The head, (Fig. 16. *g*,) supports the organs of mastication and of the senses, and contains internally the parts of the mouth, the pharynx, the commencement of the æsophagus, and the two first pairs of ganglia. We observe attached to the head an inferior lip, or *labium*, with its jointed *palpi* (Fig. 16. *a*,) and a superior lip or *labrum*, both of which extend transversely across the axis of the body, a pair of mandibles without palpi, and a pair of maxillæ provided with these jointed organs of sense. The head supports also a single pair of articulated *antennæ* (Fig. 16. *e*,) most variable in form, a *lingua*, and a pair of *eyes* (Fig. 16. *f*,) generally compound, with three simple *ocelli*.

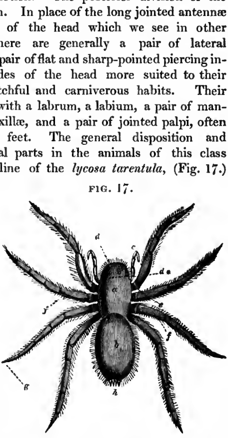
The thorax supports the legs and the wings, and is composed of three segments, the anterior of which (Fig. 16. *h*,) is termed *prothorax*, the second *mesothorax* (Fig. 16, *m*,) and the third *metathorax* (Fig. 16. *o*.) The prothorax supports the first pair of legs, the mesothorax the second pair of legs, and the first pair of wings, and the metathorax has attached to it the third pair of legs, and the second pair of wings. These segments of the thorax, like vertebræ, are composed of several elements which send processes inwards for the attachment of muscles, and the protection of the contained organs, and each of the segments exhibits a development proportioned to that of the parts it supports or contains. The parts of the legs have received names taken from those of the locomotive organs of vertebrata. Each leg is attached to its corresponding segment by a short, round, moveable articulation, called the *coxa*, or haunch (Fig. 16. *m*;) to this succeeds the *trochanter* (Fig. 16, *i*,) which is likewise a very short joint, and less moveable. The *femur* (Fig. 16. *k*,) is a strong and lengthened articulation, commonly extended horizontally, and the *tibia* (*l*,) which succeeds it is generally the most lengthened and slender joint of the leg, and directed vertically. The little joints of the *tarsus* (Fig. 16. A, B, C,) which follow,

compose the foot which commonly terminates with simple crooked *ungues* or opposeable *chili*.

The segments of the abdomen, commonly divided into an upper and a lower piece connected together at the sides by an unconsolidated portion of the integument, encompass the digestive and the generative organs, which for the most part terminate in the last segment. Each of the abdominal and thoracic segments is perforated on each side by a small spiracle or *stigma* which leads into the respiratory trachèæ ramified through every part of the body. The wings and the legs are the parts most subject to variations of form and magnitude, and their variations are accompanied with corresponding differences in the relative development of the thoracic segments which lodge the muscles and nerves of these locomotive organs. In insects where the exterior or first pair of wings are little used in progression, as in most of the coleoptera, the mesothorax is small, and the other two segments, the anterior and posterior, are large; but in dipterous insects, where the anterior or first pair of wings are alone developed, the mesothorax has assumed a proportionally great development, and the pro- and metathorax are very small. In the hymenoptera, the mesothorax is large, in the hemiptera and orthoptera, the anterior segment is most developed, and in the neuropterous insects, the meso- and the meta-thorax are large compared with the anterior thoracic segment. The mesothorax is commonly the most important segment of this region of the body, and that which best shows its component elementary pieces. We observe four elements on its tergum or dorsal surface, arranged in a single longitudinal series, the anterior of which is the præ-scutum; then follow the scutum, the scutellum, and the postscutellum. On the anterior aspect, or pectus, of the same segment, are seen the sternum single on the median plain, and arranged in pairs on its sides, the paraptera, the episternum, and the epimera. These tegumentary parts, forming the skeleton of insects, are thrown off about five times during the larva state, and once from the chrysalis before the animals assume their perfect adult form.

XII. *Arachnida.*—In those air-breathing entomoid animals, without metamorphosis, without wings, without antennæ, and with generally more than three pairs of legs, which compose the class of *arachnida,* we observe a more concentrated form of the segments, and a more consolidated condition of the skeleton on the anterior portion of the trunk than in the lower articulated classes. The segments of the head are anchylosed to those of the thorax, so as to form a single division, the *cephalo-thorax,* which supports the organs of the senses, those of mastication, and those of locomotion. The posterior division of the trunk is the abdomen. In place of the long jointed antennæ on the anterior part of the head which we see in other entomoid classes, there are generally a pair of lateral pincers, or cheli, or a pair of flat and sharp-pointed piercing instruments at the sides of the head more suited to their retired, cunning, watchful and carniverous habits. Their mouth is provided with a labrum, a labium, a pair of mandibles, a pair of maxillæ, and a pair of jointed palpi, often extended like short feet. The general disposition and form of the external parts in the animals of this class are seen in this outline of the *lycosa tarentula,* (Fig. 17.) where *a* represents the cephalothorax, and *b* the abdominal portion of the trunk. The eyes are simple small isolated ocelli, placed on the upper and anterior portion of the cephalothorax, and varying in number from two to twelve; they are of very different sizes in the same animal, and variously disposed in the different species. Four large eyes are seen at *d*, placed as at the angles of a square, and four smaller eyes are seen behind them at *d**, arranged

FIG. 17.

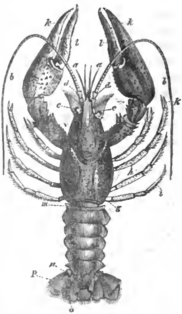


in a single transverse row. The long jointed palpi, attached to the maxillæ are seen at *c*, *c*, extended like feet. In the four pairs of legs attached to the sides of the cephalothorax, we observe the long femur *f*, extending as in insects, from the trochanter *e*; but we commonly find a smaller articulation or protibia interposed between the femur and the tibial joint. In some there are only six legs, as in insects. On the lower and anterior portion of the abdomen, or sometimes on the posterior and lower part of the cephalothorax, are placed the openings into the respiratory organs, which spiracula are found to vary in number from two to eight, they sometimes lead to pectinated simple air-sacs, and sometimes they open into extended and ramified trachēæ. Although these animals retain the form with which they escaped from the ovum, they throw off periodically their exterior covering, like the larvæ of insects; and like the crustacea, they reproduce entire legs when they have been removed from the body. The last abdominal segment of the scorpion is in form of a sting, or ossified tubular poison-duct, as we frequently see that segment in insects.

XIII. *Crustacea.*—The crustaceous animals possess the most solid form of the skeleton met with in the articulated classes. It is found in the larger decapods to contain nearly half its weight of carbonate of lime, and there is also a considerable proportion of phosphate of lime, with traces of magnesia, iron, and soda. These substances are exuded from the surface of the true skin, along with a tough coagulable animal gluten, which connects all their particles, and forms a thin varnish on the surface. The colouring matter is generally beneath this varnish, and on the exterior surface of the calcareous deposit, but sometimes it pervades the whole substance of the shell. This extravascular crust forms hollow rings to envelope the trunk, and tubular sheaths to cover all its appendices, and these are periodically cast off and renewed on the whole exterior of the body, to allow of the necessary growth of the soft parts. The head and thorax are here commonly united to form, as in arachnida, a cephalothorax, which is covered above by a large continuous

arched plate, or carapace, and supports the usual appendices for mastication, sensation, and locomotion. There are two strong mandibles, with their palpi attached to them, at the sides of the mouth; two pairs of slender maxillæ, also provided with palpi; and exterior to these there are three pairs of larger convertible maxillæ, or feet-jaws, with their attached jointed palpi, as seen in the larger decapods, as in the *astacus fluviatilis*, represented in Fig. 18. There are two pairs of antennæ, the inner pair (*a, a*,) of which are commonly divided at their free extremities, and the exterior larger pair (*b, b*,) have at their proximal extremity, in their broad expanded basilar joint, the small circular prominent opening of the vestibule or ear, on each side, directed downwards, sometimes covered with a membrane, and sometimes with a calcified plate. The eyes (*c, c*,) are compound, generally pedunculated and moveable, sometimes fixed or sessile. The upper and anterior part of the cephalo-thorax is occupied by the stomach (*e*,) with its strong muscular and osseous apparatus, and containing five teeth. In the middle of the posterior part of the cephalothorax is seen the projecting portion which covers the heart (*f*). Towards the

FIG. 18.



sides are seen the two curved longitudinal lines on the carapace, which mark the internal attachment of the membranous diaphragm, which separates the respiratory cavities on the sides from the abdominal viscera contained in the middle portion of the cephalothorax. The anchylosed segments of the cephalothorax send inwards and upwards numerous vertical thin calcified plates, which give attachment to the muscles of the haunches, and by meeting

above, they form an inferior median canal to protect the nerves and ganglia of this part of the trunk. There are most frequently five pairs of legs, which like the exterior pairs of jaws, have branchiæ attached to their bases. In the female of the decapods, we observe the round opening of the vulva in each haunch of the middle or third pair of legs; and in the male the open sheath of the penis is seen in each haunch of the fifth or posterior pair of legs. The front pair of legs are generally the most powerful, and have the last tarsal joint (*l*, *l*,) inserted high, and opposable to the penultimate articulation (*k*, *k*). The segments of the post-abdomen (*m*, *n*.) are moveable, and sometimes extend backwards in a line with the cephalo-thorax, or are short, and fold in beneath that part. Below the middle of the last small segment, is the opening of the anus, and the two last segments of the post abdomen have their lateral appendices (*p*, *o*,) in form of flat expanded caudal plates for swimming and for protecting, when folded inwards, the delicate inferior parts of the trunk, or the ova in the female. On the lower surface of the post-abdominal segments are attached the false feet, to which the ova are affixed after their discharge from the two ovaries, and from which the branchiæ are commonly suspended in the inferior orders of crustacea. The chief differences in the skeletons of this class arise from the size, and the forms assumed by the convertible lateral appendices of the segments, and the extent to which the segments are developed or anchylosed. This solid crust, forming the skeleton of crustacea, is thrown off periodically from every part of the trunk and even its most delicate appendices. This is done by the animal first detaching the cutis and muscles from the inner surface of the old shell, then excreting from the surface of the cutis a new layer of epidermis, then a deposit of colouring matter, and within this the calcareous materials of the new shell, the old having been broken off in detached pieces in succession from all parts of the body.

FOURTH SECTION.

Organs of Support in the Cyclo-Gangliated, or Molluscous Classes.

The external skeletons of the molluscous animals are consolidated by the carbonate of lime, without the phosphate which is common in the other great divisions of the animal kingdom. This earthy matter is secreted from the skin in successive layers mixed with a glutinous coagulable animal matter, which gives firmness and tenacity to the whole mass, and the skeletons are not exuviable, as in the other articulated classes. From the low condition of all the organs of relation in the molluscous animals, they are less able to perceive, or avert, or escape from danger than the free and active articulata, and they accumulate and preserve all the successive layers of their rocky covering permanently in contact with their surface. The shells of these animals are remarkable for their want of symmetry on the two sides of the body, the want of unity in their plan of formation, and their inconstancy in animals of similar structure.

XIV. *Tunicata.*—The tunicated animals have no external shell nor internal solid parts, but are covered with a tough elastic homogeneous tunic, in form of an enveloping sac, with a respiratory and an anal orifice. This exterior sac is the analogue of the valves of conchifera, and has the muscular fibres of the lining mantle inserted into its inner surface, as in the shells of bivalvia. It presents every variety of colour and consistence in the different species, and has often a coating of extraneous particles of shells or gravel adhering to its outer surface. Sometimes it extends at its lower part into numerous short processes, or into a long peduncle to attach the body to rock or other hard substances. This exterior cartilaginous

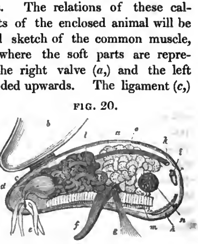
skeleton is most dense, thick, and opaque in the larger isolated forms of ascidiæ, and is most soft, delicate and transparent in the aggregated or compound forms of tunicata. Two very dissimilar kinds of tunicated animals are represented in Fig. 19, where 1, is the *cynthia papillata*, and 2, the *pyrosoma gigantium ;* the first is permanently fixed, like most of the animals of this class, and the second is an aggregate mass of numerous individuals which floats by their combined movements freely through the sea. In the cynthia we observe the transparent tough cartilaginous tunic forming a sac, which is entirely closed except at the respiratory orifice (*a*,) which admits the currents of water brought by the vibratile cilia of the gills, and the vent (*b*,) by which the currents escape from the respiratory cavity. The lining muscular tunic of the mantle is most firmly united to the sac around these two orifices, where there are also distinct sphincter muscles. At the bottom of the sac is seen the stomach (*c*,) the great branchial vein (*d*,) which dilates below the stomach to form a heart, the convoluted intestine (*e*,) the ovary (*f*,) and the liver (*g*,) enveloping the pyloric end of the stomach. The pyrosoma, Fig. 19. 2, is a long tube closed at the upper end (*a*,) open at the lower extremity (*b*,) and composed of innumerable distinct individuals (*c*, *c*,) which are similarly organized internally to the cynthia, but have their respiratory orifices on the sides of the long projecting external papillæ (*c*, *c*,) and the vents or anal orifices of all the separate individuals opening into the interior of the tube ; so that by the act of respiration alone, this transparent and luminous tube is carried up through the still seas. The exterior tunics of these component animals are thin, soft, transparent, and of a bluish white colour, and are the only parts by which they appear to be united together. In some of the compound forms of these tunicata, however, the enveloping tunic has a third opening, which admits the currents of respiration or circulation to extend from one individual to another.

FIG. 19.

XV. *Conchifera.*—The shells of these animals consist

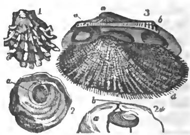
generally of two moveable pieces or valves placed on the exterior of the body, and connected together by ligaments and muscles. These valves are composed of carbonate of lime mixed with an albuminous coagulable matter, which is secreted chiefly by the glandular pores on the exterior surface of the lining mantle. The valves grow by the successive addition of larger layers to their inner surface, and the limits of these superadded laminæ are commonly marked by distinct striæ on the outer surface of the shells. As the calcareous laminæ are cast upon the surface of the mantle which envelopes all the soft parts of the body, the shells vary in their form according to the shape of the enclosed animal, and especially of the secreting glandular portion of their lining membrane. The exterior surface of the valves is covered with a thin layer of the same albuminous matter which unites the particles of the shell; this forms a dense and tough varnish or epidermis, which protects the colouring matter immediately beneath it, and the whole texture of the solid layers. Although most of the conchifera are bivalved, some, as the *pholades*, possess small supplementary pieces at the hinge of the valves, and are thence called multivalves. The relations of these calcareous shells to the parts of the enclosed animal will be perceived by the annexed sketch of the common muscle, *mytilus edulis*, Fig. 20, where the soft parts are represented as attached to the right valve (*a*,) and the left valve (*b*,) is opened and folded upwards. The ligament (*c*,) connects the two valves together, and tends by its elasticity to open them to a limited extent. The ligament of bivalvia grows like the shell by successive internal layers, and is placed at the hinge, where there are generally processes of the shell termed teeth, which lock into each other when the valves are closed. The position of the stomach (*d*,) with the short œsophagus, and the two pairs of long labial tentacula (*e*,) mark the

FIG. 20.



anterior part of the shell. The muscular foot (*f*,) extends from the ventral surface of the body, where we see also the byssus (*g*,) by which the delicate mytiloid shells are fixed to solid bodies. The respiratory orifice (*h*,) is placed at the most open part of the shell, and near this is the vent (*i*,) by which the respired water and the excretions are discharged. The rectum (*k*,) opens near to the vent after perforating the ventricle of the heart. The large lobes of the liver (*l*,) envelope the turns of the intestine, and the pyloric portion of the stomach. On the ventral or inferior surface of the abdomen, is the respiratory cavity in which are seen the four long pectinated laminæ of the gills (*m*,) and towards the posterior part of the shell is the strong adductor muscle (*n*,) by which the valves are drawn forcibly together when the animal is alarmed. The ovary (*o*,) fills a great portion of the posterior and upper part of the shell. From this position of the soft parts within the valves, we perceive the anterior part (*d*,) of the shell to be that next the mouth (*e*,) and the posterior part (*b*,) to be that next to the anus (*k*,) and the vent. The dorsal margin (*a*,) of the valves is that next to the liver and ovary, and the ventral part is that which encloses the respiratory gills (*m*) ; we also observe from these parts the reason for designating the one valve (*a*,) the right, and the other (*b*,) the left, as we term the lateral parts of the skeleton in higher animals. As these shells of conchifera are extravascular exudations from the surface of the mantle, they are incapable of growth but by superposition of new parts, and the various spines and laminæ, which are so often developed on their exterior surface are mere depositions from the edge of the mantle, and indicate former positions of the margin of the valves. The ordinary direction in which these processes of the shells are formed is seen in the long narrow projecting laminæ of the *spondylus gæderopus*, (Fig. 21. 1.) where they are arranged, with great symmetry, in rows which are regular both in the longitudinal and transverse directions, and indicate the positions of the processes of the mantle which excreted them. The adductor muscle of the valves leaves a depression on the inner surface of each, which marks its place of insertion and its form, and which

FIG. 21.



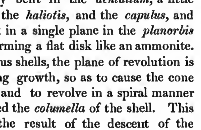
is termed the muscular impression. When the shells have a short and round form, as the *spondylus*, (Fig. 21. 1.) the *anomia*, (Fig. 21. 2.) the *ostrea*, there is commonly but one adductor muscle, and one muscular impression, and these are *monomyaria*; when the valves have a more lengthened form, as the *arca*, (Fig. 21. 3.) the *tellina*, and many others, there are at least two muscles and two muscular impressions, and these form the *dimyaria*. The hinge of the valves is supported by the ligament, and formed by the teeth which afford the most obvious, regular and constant characters for the discrimination of these shells. The teeth are seen in the figure of the *arca barbata*, (Fig. 21. 3. *a*,) projecting from the whole extent of the hinge, and the two muscular impressions are seen in the interior towards the ends of the valves. The epidermic filaments which give a barbed appearance to the surface of this and many other shells, are merely uncalcified marginal projections of the albuminous matter which pervades all the successive layers of the valves. In the *anomia*, (Fig. 21. 2, and 2*,) there is a circular perforation (*a*,) in the flat valve, through which the central portion of the adductor muscle passes to be inserted into a third small circular calcareous piece, which is permanently fixed to some extraneous solid body. The periphery of the adductor muscle is inserted into the flat valve around the margin of the hole; so that the muscle here secretes the calcareous matter of the small fixed opercular piece into which it is inserted, as the muscular foot of a gasteropod secretes the calcareous operculum which covers the orifice of its shell. There is a great difference in the extent to which the right and left valves resemble or differ from each other. Some are equivalve, or have their two valves alike in form, as the *cardium*, the *mactra*, the *solen*, the *pholas*; some, as the *tridacna*, are sub-equivalve, or have them nearly alike; and others as the *anomia*, the *terebratula*, the *gryphæa*, are inequivalve,

or have the valves very unlike each other. The waved disposition of the calcareous particles in the layers of these shells, often gives them a beautiful nacreous lustre, especially in the more pellucid internal layers, which constitutes the mother-of-pearl; and when spherical globules of this matter, composed of concentric layers enveloping some extraneous particle, are secreted by the mantle and unconnected with the shell, they form the rich pearls of commerce. The edge of the mantle sometimes extends itself beyond the margin of the valves, so as to touch some extraneous body, and by their exuding the usual calcareous and albuminous matter, it causes the contiguous surfaces to become cemented together; in this manner the oyster glues its shell immovably to the rocks at the bottom of the sea.

XVI. *Gasteropoda.*—The shells of the gasteropods are composed, like other molluscous shells, of carbonate of lime with animal matter. They are extravascular, and generally excreted from the outer surface of the skin in the form of hollow unilocular laminated cones, which envelope the exterior of the animal, and they grow by the addition of successive layers to their inner surface. They take the form of the exterior of the body, especially of the mantle, and they are permanently connected with the muscular system. The laminæ which compose these shells have generally a fibrous structure, and the parallel fibres which form them have a zigzag direction nearly vertical to the surfaces of the layers. They are generally covered with a thin epidermic varnish, which protects the colouring matter of the surface; their outer layers are commonly more loose, opaque and porous than the dense, pellucid, glassy layers of the interior, and they are often provided with an operculum which is sometimes horny, sometimes calcareous, and is permanently attached to the muscular foot which secretes it. Many gasteropods have no shell, as the *scyllæa*, the *tritonia*, and the *doris;* some have a thin calcareous lamina within the skin of the back, as the *aplysia*, and some have an external shell so small as to cover only a portion of the animal's surface, as the *testacella*, the *cryptostoma* and the *carinaria*. The shell is perforated in the *haliotis* the *fissurella* and the *emarginula*, and it is composed of eight trans-

verse parallel imbricated pieces in the *chiton.* It is however most generally in form of a hollow cone, wide and open at the base, closed at the apex, and more or less convoluted or spiral. This cone has been considered as analogous to the two valves of the conchifera united together. It is short, wide, and nearly straight in the *patella*, more lengthened, narrow, and slightly bent in the *dentalium*, a little twisted in the *crepidula*, the *haliotis*, and the *capulus*, and it revolves round its apex in a single plane in the *planorbis* and some of the *helices*, forming a flat disk like an ammonite. In most of the gasteropodous shells, the plane of revolution is constantly changing during growth, so as to cause the cone to turn to the right side, and to revolve in a spiral manner round an axis or pillar called the *columella* of the shell. This spiral twist appears to be the result of the descent of the foot over the columella, and the influence of the great centres of the circulating and respiratory systems on the left side of the body ; so that the apex of the spire is on the right side of the animal, and the canal of the shell for respiration is on its left side. In a few reverse shells, where the spire lies to the left side of the aperture, the circulating and respiratory organs are found transposed to the right side of the animal. The general disposition of the soft parts in the cavity of a spiral unilocular univalve shell will be seen by this diagram of the common *buccinum undatum*, Fig. 22, where the animal is represented as creeping upon its expanded foot. The upper and back part of the foot supports the operculum (*m*,) which closes up the aperture of the shell when the animal is retracted. The adductor muscle (*b*,) is attached to the columella, and is the only part of the body adhering to the shell. The mantle (*i*, *g*, *a*, *k*, *e*, *f*,) is open in front,

FIG. 22.

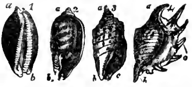


lines the aperture of the shell, secretes the calcareous layers, and covers the respiratory organs (*g*.) The muscular funnel (*i*,) extends through the canal on the left side of the aperture of the shell, and leads the currents to the two branchiæ

(g,) at the base of which are the auricle and the ventricle (h.) On the right side, within the mantle, is seen the anal orifice (k,) and the male organ (f.) The head (d,) provided with two fleshy tentacula, with little black eyes at their base, is extended from a short muscular neck, and projects from the mouth a long powerful proboscis, furnished at its extremity with sharp recurved conical horny teeth (e.) The closed and tapering part of the shell is occupied by the turns of the liver and testicle in the male, or the liver and ovary of the female, which organs accompany each other to the apex of the spine. When the animal creeps forwards, covered with its shell, it extends its foot, its head and its neck from the aperture in such a manner that the upper lip of the shell lies over the free edge of the mantle above the head, and the foot extends over the lower lip, or the columella. The columella, or pillar, is the axis of revolution, and is sometimes perforated through its interior with a cavity called the *umbilicus*, which has no communication with the cavity of the cone containing the animal, but tends to lighten massive shells, where the wide revolutions are at a distance from each other.

As the calcareous layers of the shell are chiefly secreted and formed by the anterior glandular portion of the mantle, which is a part most liable to vary in its form according to the age and the season, the chief differences in gasteropodous shells are those produced by the diversified forms of the upper lip. In the young animals the upper lip of the shell is generally quite even and smooth, and corresponds with the simple condition of the margin of the mantle, but at maturity this upper secreting portion of the mantle often assumes a highly developed, folded, or fimbriated edge, and the upper lip of the shell takes a similar form. In the young *strombus gigas*, the upper lip is quite even and uniform with the ordinary turns of the cone, but at maturity it expands, thickens, folds backwards, and becomes effuse. The shell of the *pterocera scorpio*, in its young state, (Fig. 23. 3,) has the ordinary simple thin, incurvated margin of other growing shells; the canal, (Fig. 23. 3. b,) appears short and truncated, and the apex of the spire (Fig. 23. 3. a,) pro-

FIG. 23.



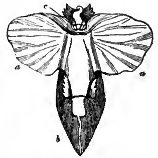
jects, naked and acute, from the opposite end of the shell. But as it approaches maturity, (Fig. 23. 4,) the upper lip expands, becomes effuse, extends to the right and to the left side, so as to conceal the apex of the spire, (Fig. 23. 4. *a*,) and lengthen the canal (Fig. 23. 4. *b*,) and it shoots upwards several processes which are at first thin and hollow open canals, (Fig. 23. 1. *c*,) and are gradually filled up with successive layers, and converted into solid spines, which entirely change the appearance of the shell. These changes of the upper lip take place periodically, and at regular intervals during the development of many shells, as in the *murices*, thus producing transverse rows of variously formed processes from the outer surface of all the turns of the cone. The young and the adult shells of the *cypræa* are scarcely recognisable as belonging to the same individual, from the changes of form they experience at maturity. The form of the young shell of the *cypræa exanthema* is represented in Fig. 23. 2, where the aperture is wide, the upper lip thin and even, the canal (*b*) projecting, and the apex (*a*) of the spire extended and free. But in the adult form (Fig. 23. 1,) of the same shell the aperture is contracted, narrow and serrated, the upper lip is thickened and rounded backwards, the canal is converted into a groove, and the whole of the spire is covered and concealed. These adult changes in the cypræa are produced by the extension of the sides of the mantle over the upper and lower lips of the shell, and now the new layers are added to the exterior surface, as if it were an internal shell, and the line of junction of the two enveloping folds of the mantle is marked by a transverse discoloration or groove on the exterior of the shell along the whole of its convex dorsal part. By this addition of new layers to its whole exterior surface, the adult cypræa has a smooth, glistening, naked and variously coloured exterior, like the interior surface of most other shells, and can present no rough epidemic covering when arrived at that state. In the *cypræa*, the *dolium*, the *harpa*,

and many others, the interior surface of the shell has experienced no change by being long in contact with the living soft parts of the contained animal; the grooves, the striæ, the prominences, and even the colouring matters which were upon the outer exposed surface in the young condition of the shell, still preserve in the adult state, their primitive appearance and integrity throughout the whole interior of the revolutions. These have grown by the revolution of the upper lip around the columella; but many others add new layers also to the inferior or columellar lip during their growth, thus covering over the superficial external layers on the left side of the revolutions, and generally presenting strong parietes and a thick and solid columella, as in the *strombus gigas*. In many forms, however, as in the *cones* and *olives*, where the widely expanded upper lip sufficiently covers and protects the smaller revolutions, the total weight of the shell is diminished without weakening its exposed part by carrying forward the calcareous matter from the inner first formed concealed revolutions, and depositing it upon the exterior surface of the last or outer turn of the shell which alone is exposed to danger from external causes. The vertical, zig-zag, parallel fibres composing the thick parietes of these shells is distinctly preserved in their fossilized remains. The hybernating gasteropods, as the *snails*, which want an *operculum*, close up the aperture of their shell, when they retire to their winter slumber, with a thick deposit of calcareous matter, called an *epiphragma*, which is not connected with the muscular foot, like the true operculum of other shells, but only with the aperture of the cone. The operculum is a permanent part attached to the contained animal, and the epiphragma is a deciduous part attached only to the orifice of the shell.

XVII. *Pteropoda.*—As the pteropodous animals are not provided with a muscular foot to creep upon a solid surface, but are all organized to swim freely through the sea by means of muscular expansions like fins, they are never encumbered with a massive or heavy skeleton. Their skeleton, when present, is generally external, extravascular, thin, pellucid, horny, or vitreous; it is univalve, unilocular, of various forms, generally without a spiral twist,

capable of enveloping the whole body, and it is destitute of an operculum, as in most of the light shelled floating gasteropods, and the swimming testaceous cephalopods. The annexed figure of the *cymbulia* of Peron (Fig. 24,) represents a typical form of a testaceous pteropod from the Mediterranean, as swimming with its expanded fins (*a*, *a*,) which support the branchiæ, and covered below with its thin, lengthened, fusiform, carinated and serrated shell (*b*.) The upper part of its body (*c*) between its muscular and highly vascular fins (*a*, *a*,) appears to present two tentacula, two eyes, and an extended proboscis. The thin diaphanous, conical shell of the *spiratella* is twisted spirally on itself, and with its apex on the left side, like a *turrilite*; the delicate pellucid shell of the *hyalea* enveloping the round body of the animal is tricuspid below; in the shell of the *cuvieria columnella* there is a partially formed chamber at the lower closed extremity; and in the *creseis virgula* the shell has a long, straight, conical form, common to the belemnites, baculites, orthoceratites, and many other extinct cephalopods.

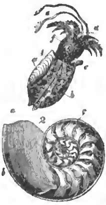
FIG. 24.



XVIII. *Cephalopoda.*—In this highest of the molluscous, and of all the invertebrated classes, we trace the gradual disappearance of the external unorganized shells of the invertebrated tribes, and the commencement of the internal organized bones of the vertebrata. The shells are sometimes external, as in the *nautilus*, and sometimes internal, as in the *sepia*, and they are consolidated by the carbonate of lime, as in the lower molluscous classes. They are almost always polythalamous, and without an operculum. Many of the extinct shells have the form of straight cones, as belemnites, baculites, and orthoceratites; some are curved, as hamites and scaphites, some are convoluted and orbicular, as the spirula, the nautilus, and the ammonites, and some, as the turrulites, are spirally twisted, like the turbinated shells of gasteropods. The

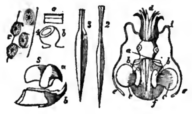
several chambers of these polythalamous cones communicate with each other, sometimes by means of a prolonged calcareous syphon, as in the spirula and nautilus, sometimes by one or more simple foramina in the partitions. As the cephalopods do not creep upon a muscular foot, like the slow-moving gasteropods, but for the most part swim freely through the sea, their shells are thin and light, and sometimes consist of simple straight laminæ unconsolidated by calcareous matter. The form and structure of the external polythalamous shells of the cephalopods is seen in the section of the *nautilus pompilius*, represented in Fig. 25. 2, where (*a*,) shows the interior of the last formed chamber, in which the animal is fixed by two muscles of attachment. The syphons (*b*,) by which all the posterior chambers (*c*,) communicate with each other, are seen to extend for a short distance, tapering from before backwards, into each of the succeeding chambers. These separated partitions and chambers of this convoluted cone have nearly the same relations to each other and to the contained animal, as the successive contiguous layers of the convoluted shell of a gasteropod, and they are formed in the same manner by periodical exudations of calcareous matter from the exterior surface of the mantle. In the *spirula*, the long calcareous syphon of each septum extends through the whole of the chamber, and into the commencement of the next succeeding syphon ; so that there is a continuous calcareous tube passing through the whole shell on the inner concave side of its convolutions. The shell of the *sepia*, (Fig. 25. 1. *a*,) affords an example of an internal shell belonging to this class. It is contained within the substance of the dorsal part of the mantle, and consists of numerous nearly flat layers, placed within each other, the first formed being at the outer part and posterior termination of the shell, and the succeeding new layers extending always more forwards than the edges of the old.

FIG. 25.



These compressed layers are connected together by innumerable, very minute tubular fibres; so that there is a great analogy between the structure of this internal laminated shell, and the external polythalamous shells, where the successive laminæ are more detached. In the figure of the sepia (Fig. 25. 1,) the mantle has been cut open at (*a*,) to show the position and the successive layers of the shell. The lateral muscular fins (*b*,) by which the animal swims, extend along the whole sides of the abdomen, the *funnel* (*c*,) for the passage of all the excretions, extends from the anterior part of the open sac. In the centre of the arms or feet, radiating from the head, is placed the mouth (*d*,) provided with two dense and sharp mandibles, and the two long muscular tentacula (*e*,) extend from the fore part of the head (*f*,) between the first and second pairs of feet. In many of the naked cephalopods the dorsal shell contained within the substance of the mantle is destitute of calcareous matter, and reduced to a mere thin, flexible, transparent, cartilagenous lamina, as we find in the *loligo*, the *sepiola*, the *loligopsis*, and others. These uncalcified shells are contained in a dorsal sac of the mantle, like the calcareous laminated shell of the *sepia*. The position of the thin, stiliform, cartilaginous lamina in the lack of the *sepiola vulgaris*, is seen in (Fig. 26. 1. *a*,) where the coloured covering and skin have been removed to show the situation of the hard parts and the superficial muscles. The dorsal lamina (*a*,) is here very small, flexible and short from the great mobility of the muscular part, which forms its sheath. In the *loligopsis guttata*, the dorsal lamina (Fig. 26. 2,) extends the whole length of the back of the mantle to the point of the tail, being spear-shaped, with very thin flexible edges, especially at its broadest middle part. That of the *loligo sagittata*, (Fig. 26. 3,) is more broad and leaf-shaped, and extends, as most of the other soft,

FIG. 26.



cartilaginous, internal shells, from the upper edge of the mantle to the point of the tail, being contained loose in a closed dorsal sac of the mantle. In the *octopus*, the dorsal lamina is wanting, but there are two small lateral stiliform, loose, cartilaginous pieces contained in the substance of the mantle, as the median shell in other species.

In this highly complicated class of molluscous animals, which approach so near to the cartilaginous fishes in the structure of many of their internal parts, we already find several internal rudimentary pieces of an organized cartilaginous skeleton. The brain encompassing the œsophagus is enclosed in a large curved cranical bone, which forms also part of the orbits on each side, contains the cavities of the ears, and has numerous muscles inserted into it. Other cartilaginous, organized pieces are seen extending downwards from the back part the skull, like the rudiment of a vertebral column. Two clavicular pieces in front unite to the first rudiments of a sternum, and attach the sides of the mantle to the trunk, and there are generally two scapular pieces, more or less firm, extending along the sides to which the muscles of the lateral fins are attached. These two scapular pieces are seen in the *sepiola vulgaris*, (Fig. 26. 1.) *b*, where they support the arms (*c, c*,) and are freely moveable on the back, like the scapulæ of vertebrata. We also perceive muscles inserted into the strong upper and lower mandibles (Fig. 26. 5. *a, b*,) of these animals, formed like the bills of a parrot. The suckers of the arms, (Fig. 26. 4. *b, c*,) whether sessile (*c*,) or pedunculated (*b*,) have their inner circular margins supported, each by a firm cartilaginous circular plate (*a*,) with minute sharp teeth extending inwards from one of its sides, by which the action of these prehensile organs is aided. In the *onychia*, there are dense, sharp, curved, conical spines placed in these suckers, like the conical teeth disposed on the oral disk of lampreys, among the lowest of the cartilaginous fishes.

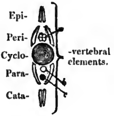
FIFTH SECTION.

Organs of Support in the Spini-Cerebrated or Vertebrated Classes.

In the lowest vertebrated animals we still find traces of the external unorganized shells of inferior classes, in the form of calcareous scales in fishes, and of horny plates in many reptiles; but these are generally reduced to small detached pieces, and do not serve as organs of support. The organs of support in the vertebrated classes are placed within the soft parts, so that these animals are more intimately related to the properties of surrounding objects and outward nature, by the sensibility and delicacy of their surface. Their skeleton being internal, it is not exuviable in a mass, and as it cannot grow and preserve its proportions by the simple addition of layers to its surface, it is organized or permeated in all directions by vessels which take away and replace its materials atom by atom. The phosphate of lime, which forms the chief consolidating earth, increases in its proportion to the gelatin as we ascend through the vertebrated classes; so that the bones of the lowest fishes are soft, flexible, and cartilaginous; those of hot-blooded classes are of great density and strength, and those of reptiles possess intermediate properties. The bones have a fibrous structure, which is the best adapted for the transmission of minute vessels through their texture. They form solid levers for the motions of the body, and cavities to protect its viscera. The most constant and the first formed part of the skeleton is the vertebral column, which is composed of moveable vertebræ, each of which consists of several elements that are found most isolated and distinct in the lowest classes, and in the embryo state of the highest. The elements which

appear most constant and distinct in the composition of a vertebra are the round central body, or *cyclo-vertebral* element, the two superior laminæ or *peri-vertebral* elements which encompass the spinal chords, the two portions of the superior spinous process, or the *epi-vertebral* elements, the two inferior laminæ, or *para vertebral* elements, which form a cavity for the blood-vessels, and the two portions of the inferior spinous process, or the *cata-vertebral* elements. The most frequent position of these nine component elements of a perfect vertebra is shown in the annexed diagram, (Fig. 27.) where (*a*,) represents the spinal cord protected by the two peri-vertebral

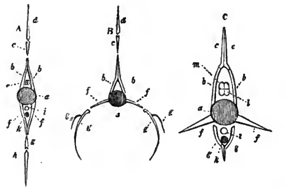
FIG. 27.



pieces; (*b*,) is the common position of the artery, and (*c*,) of the vein beneath the bodies of the vertebræ in most parts of the column, and these are embraced by the two para-vertebral elements. The cyclo-vertebral elements are tubular in the articulated classes of animals where they envelope the whole trunk as hollow segments, they are nearly solid to their centre, and present two concave surfaces in fishes; they are convexo-concave in reptiles, and have flat surfaces in mammalia. They are the most constant and typical parts of the vertebral column. The other vertebral elements vary their forms and positions chiefly according to the dimensions of the organs they embrace, and the extent of surface required for muscular attachment; consequently they vary much in different parts of the same column, and in the skeletons of different classes. Three very different positions of the same vertebral elements are represented in this

diagram (Fig. 28,) where A shows their most common positions with relation to each other in the caudal portion of the skeleton of an osseous fish where they are designed to give great extension for the attachment of the powerful lateral muscles which move the tail. The body of the vertebra, or cyclo-vertebral element (*a*,) supports the two superior laminæ or peri-vertebral elements (*b*, *b*,) which early unite above to form the small foramer for the spiral cord (*e*); and beyond their termination we observe the interspinous bone (*c*,) and the ray (*d*,) of the

FIG. 28.

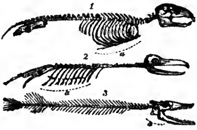


external fin, which are the two epi-vertebral elements placed in a vertical line. The analogous elements are seen on the lower part of the vertebra, where the two inferior laminæ (*f*, *f*,) or para-vertebral elements, form a larger foramen for the lodgment of the great continuation of the aorta (*i*,) above, and the *vena cava* (*k*,) below. The inferior interspinous bone (*g*,) and the ray (*h*,) of the external fin, are the two cata-vertebral elements placed in a vertical line, like the epi-vertebrals above. These vertebral elements often assume, in the region of the abdomen in fishes, the position marked in the diagram B, of Fig. 28, where the superior elements remain as in Fig. A, but the inferior laminæ (*f*, *f*,) or para-vertebrals, are stretched out in a horizontal direction, and have the two cata-vertebrals (*g*, *g*,) extended from their ends in

form of a pair of ribs to encompass the organs of this part of the trunk. The vertebral elements situate above the body of the bone expand in the region of the head in the same manner as we here see those below the cyclo-vertebral element in the region of the abdomen; and this they do in order to encompass the soft parts contained in the cavity of the skull, and in the face. Another position of these vertebral pieces, which is common in the caudal region of the column in higher classes, especially among the long-tailed reptiles, and in cetaceous mammalia, is represented in the diagram C of Fig. 28, where we observe the large foramen for the nervous columns (*l*,) above the cyclo-vertebral element (*a*,) requiring the whole extent of the two peri-vertebrals (*b*, *b*,) for its formation, and the strong superior spinous process is composed of the two epi-vertebrals placed side by side. In the lower part of the same vertebra the inferior laminæ extend outwards to form strong transverse processes (*f*,*f*,) and an inferior spinous process, and an inferior foramen for the aorta (*i*,) and the vena cava (*k*,) are formed by the approximation of the two cata-vertebrals (*g*, *g*,) which show their displacement by being generally thrust backwards between two cyclo-vertebral elements. When the two cata-vertebral elements are extended outwards to form ribs in fishes, we very often find them bifurcated, as represented in Fig. 28. B, *g*, *g*. The general form of the vertebral elements is very much modified and varied in different parts of the column by the shape and magnitude of the parts these elements embrace, and the extent of surface for muscular attachments which they require to present. The epi- and peri-vertebrals are most expanded in the skull and the sacrum, and the para- and cata-vertebrals, where they embrace the viscera of the trunk. The appearance of the entire skeleton of vertebrated animals is greatly varied by the difference in the position of the ribs, or of that part of the column where the para- and cata-vertebral elements are extended over the great viscera of the trunk. In fishes, as shown in the annexed figure, (Fig. 29. 3,) and in cetaceous mammalia, the fixed, ribbed, and thoracic part of the column (*a*,) is placed near its anterior extre-

mity, and all the posterior portion is freely moveable, to give impulse to the tail in swimming. In birds, (Fig. 29. 2,) where the head and neck are used as a hand and arm, for all prehensile purposes, the fixed thoracic portion (*a*,) of the column is placed near to its posterior extremity, and the anterior portion is free for extensive motion. Most quadrupeds (Fig. 29. 1,) and reptiles, balanced on two pairs of extremities, hold an intermediate place, and have the ribbed and solid portion (*a*,) of their trunk placed near the middle of the column.

FIG. 29.

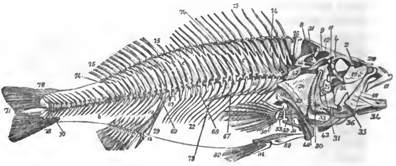


XIX. *Pisces.*—The bones of fishes contain less gelatine, and a larger proportion of water than those of higher classes, and are less dense and compact in their texture. The soft bones of cartilaginous fishes yield more water than those of osseous fishes, and they contain the soluble salts of soda, the chloruret, the sub-carbonate, and the sulphate, while the more dense bones of osseous fishes are strengthened, like those of higher classes, with the more insoluble phosphates. The bones of fishes resemble those of the embryos of higher animals, not only in their soft, gelatinous, or cartilaginous character, but also in the isolated condition of all the elements, or centres of ossification, of the more complicated bones, especially of the head. The skeleton of fishes consists almost entirely of the vertebral column, from the extremity of the face to the end of the tail, like that of the embryos of mammalia at a corresponding stage of their development. The bodies of the vertebræ are composed of concentric layers, as represented in Fig. 30. *a*, which are broadest at the circumference, and become narrower as they approach the centre, where there is commonly a small hole (Fig. 30. *b*, *b*.) These bodies are therefore concave both on their anterior and posterior surfaces, and when applied to each other, they leave large intevertebral spaces between them, which

are filled up each with a short sac of a gelatinous thin fluid, as seen in Fig. 30. C. *c*, so that these vertebræ play freely over the surface of so many elastic interposed balls. The bodies of the vertebræ are the elements first developed in the animal kingdom. They are the most important, as means of support; they are the parts most developed in the vertebræ of fishes, and the skeletons of the lowest cartilaginous species, are composed almost solely of these elements. Even in the sharks, the other elements are remarkably small and are not anchylosed to the bodies of the vertebræ; so that by maceration they fall off, and leave deep depressions (Fig. 30. B, *c*.) in the sides of the cyclo-vertebral elements where they were attached. By the great size of the central passage in the bodies of the vertebræ of many cartilaginous fishes, the inter-vertebral substances communicate with each other, and form a continuous elastic beaded chord passing through the whole vertebral column, as in the lampreys. The component elements of the vertebræ of fishes are disposed in such a manner as to give great vertical extension to the trunk, and thus to form a broad lateral surface to strike the water in their horizontal mode of progression. As the spinal chord is small, the upper vertebral foramen is also small in fishes, and the two superior laminæ therefore soon meet to form a spinous process by their junction, as seen in the skeleton of the perch, (Fig. 31. *c*, *c*, *c*.) Along the greater portion of the back, we observe the two epi-vertebral elements (Fig. 31. 74, 75,) placed end to end in a vertical direction, the short inferior portion forming the *interspinous bone*, (74,) and the more slender superior portion extending from the trunk and covered with a prolonged fold of the skin, forms a *ray* (75,) of the dorsal fin, and thus are constructed all the *dorsal fins* placed along the middle of the back from the head to the tail. The same two elements in several of the last cocygeal vertebræ, pass backwards in a very oblique manner, and constitute the *caudal fin* (70, 78.) The corresponding elements below the

FIG. 30.

FIG. 31.



bodies of the vertebræ occupy the same relative position wherever there are *anal fins* developed between the tail and the anus, as at *a*, 72. The inferior foramen of the vertebræ, for the blood vessel is larger than that above for the spinal chord, and it widens much in the pelvic region (83,) in order to embrace the posterior parts of the urinary and genital organs. The elements of the cocygeal vertebræ of fishes being thus extended upwards and downwards, they present no transverse processes in that region to impede the lateral motions of the tail, and their nervous and vascular systems are here protected from injury during the violent actions of that part of the body. In the region of the abdomen the inferior interspinous bones and the rays are placed at the ends of the transverse processes, and extended more or less round the viscera, as ribs (72,) which often present a bifurcated appearance by their sending a long process (73,) outwards and backwards. The ribs are often merely minute epiphyses at the ends of the transverse processes, as in the rays and sharks, and they are continued forwards along the vertebral column to the atlas; so that there are no distinct free cervical vertebræ. The bodies of the cranical vertebræ continue along the floor of the cranium through the basilar part of the occipital bone, the body of the sphenoid, the ethmoid, and the vomer; and these parts are here extended forward in the same straight line with the rest of the vertebral column. The ordinary concave

ends of the bodies of the vertebræ can be traced forward to a variable extent through those of the cranium, as at both ends of the basilar portion of the occipital, and of the body of the spenoid. The bones of the cranium in osseous fishes are generally thin, diaphanous, elastic, united by squamous sutures ; they present a large exterior surface for the attachment of the powerful muscles of the trunk, and they continue to grow and to preserve the same proportions to the rest of the skeleton through life. The interior of the large cranical cavity is filled chiefly by the soft cellular tissue of the arachnoid coat, the brain occupying but a small portion of the base of the skull. The number of distinct osseous pieces in the composition of the skull is greatest in fishes, and they correspond nearly with the theory of this part of the skeleton, being composed of seven vertebræ, each consisting as usual, of a body with four elements above, and four elements below. The number of separate pieces diminishes as we ascend through the vertebrated classes, by the early and permanent anchylosis of a variable number of these elements common to all forms of crania.

The spine of the occipital bone, or the superior occipital (8,) is here large for muscular attachments, like that of the vertebræ of the trunk; and this ridge is often continued forward over the whole skull to the nose. From the horizontal position of the head on the trunk, the occipitals and the frontals generally meet and force the parietals (7,) to assume a lateral position, as we see in the skulls of cetacea, for the same reason. The elements of the temporal bone are large, detached, and mostly moveable. The petrous portion is exterior to the organ of hearing in the osseous fishes, and surrounds that organ, imbedding it in its substance in the cartilaginous species, as in higher classes. The principal frontal bones (1,) are long and bounded before and laterally by the anterior frontals (2,) and on the posterior and lateral part by the posterior frontals (4,) as in other oviparous vertebrata. The jugal (19,) is generally long, curved, and slender, as in the blowing cetacea, and composed of a series of separate pieces, which bound the inferior margin of the orbit, they form the suborbital bones of Cuvier.

The detached condition of the bones of the head is most remarkable in those of the anterior part of the face, where the palatine bones (22,) extending longitudinally on the sides of the mouth, and often covered with teeth, as in serpents, are freely moveable. The superior maxillaries (18,) extending downwards laterally behind the intermaxillaries (17,) on each side of the face, are loosely articulated to the vomer (16,) and to the palatine bones, and are freely moveable in the osseous fishes, as are also the intermaxillaries (17,) which bound the fore part of the upper jaw. The lower jaw is generally composed of at least two pieces on each side, the dental portion (34,) in front containing the teeth, and the articular portion (35,) behind connected with the head by a tympanic bone, (below 27,) considered by Cuvier as the jugal. Fishes have teeth implanted in almost every bone around the interior of the mouth, in the intermaxillary, superior and inferior maxillary bones, on the branchial arches, pharyngeal bones, palatine bones, os hyoides, and on the tongue itself. The teeth are almost entirely osseous, without fangs, and without alveoli; irregular in size and position, generally recurved spines placed in numerous rows, and they often become anchylosed to the bones which support them. Their soft osseous texture, their thin covering of enamel, and their feeble attachment, correspond with the soft condition and the imperfect union of the bones which support these prehensile teeth, as we see also in amphibia and serpents. Where the bones of the head, which support them, are strong, and firmly united, as in crocodilian reptiles and mammalia, the teeth are more dense, covered with a thicker layer of enamel, provided with fangs, and lodged in deep alveoli. Behind the lower jaw is placed the operculum, consisting of a large opercular bone (28,) a sub-opercular bone (32,) an inter-opercular bone (33,) and often an additional small piece below the sub-opercular. As fishes have no tympanic cavity of the ear to confine their ossicula auditus, the opercular bone is considered as an enlarged stapes, the sub-opercular bone as the os orbiculare, the inter-opercular as the malleus, and the fourth small bone as the iocus. These are placed behind the pre-opercular bone, (30,)

and have been also regarded by some as elements of the lower jaw.

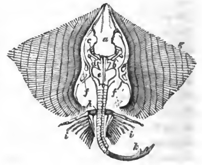
The arches, which hang down from the sides of the vertebral column, are more like ribs in fishes than in higher classes, as the lower jaw, the os hyoides, the scapular arch, and that of the pelvis. The os hyoides is very large here, as in all water-breathing vertebrata, from its supporting the branchial arches ; it consists of five pairs of pieces besides the body or lingual bone ; it is suspended from the temporal bones, and it is chiefly by its motions backwards and forwards that respiration is effected, not only in fishes, but in amphibia and chelonia. It forms the second arch below the head, between the arch formed by the lower jaw, and that formed by the scapular and coracoid bones. Its sides support the four pairs of branchial arches, the analogues of tracheal rings, and its exterior gives attachment to the branchiostegous rays of the opercular membrane.

The arms of fishes, or their pectoral fins are almost always more developed than their legs, or ventral fins, and they are generally attached to the back part of the skull, by means of an osseous arch composed behind of the two scapulæ, and before of the two coracoid bones. In the perch (Fig. 31.) the two highest or first portions of this arch on each side (46, and 47,) are regarded as the scapulæ, the long angular bone (48, 48.) attached to these, as the humerus, the two succeeding bones (51, 52,) as the ulna and the radius. To these succeed the bones of the carpus (53,) and this member is terminated by the long and numerous phalanges of the fingers. The small styliform termination (50,) of the scapular arch, composed sometimes of one, and sometimes, as in the perch, of two pieces (49, 50,) is considered as the coracoid bone, and they occasionally meet in front, as in higher oviparous classes, though without the intervention of a sternum. The relative magnitude of the arms of fishes, and their constancy, compared with the posterior members, corresponds with their great size in the embryo of higher classes, and their preceding the legs in their development from the trunk. The posterior members, the legs, or the ventral fins of fishes (80, 81, 82,) are unconnected with the vertebral column, suspended from

two rib-like iliac bones, and placed on the lower part of the trunk, sometimes near the anus, sometimes near the head, or between these two parts. The iliac bones not being here attached to the vertebral column, there is no portion of that column fixed to form a sacrum, and the same is observed in the cetacea, and the perennibranchiate amphibia, where there is no sacrum, and the whole column behind the head is thus free for the extensive motion required in swimming. These two pelvic bones (80,) are sometimes closely applied to each other, extend along the middle of the abdominal surface, like two pubic bones, and are attached to the scapular arch, or to the humeri (48,) as in the perch. In the apodal fishes, as the eels, the pelvic bones (80,) are wanting, as well as the legs; and in the abdominal fishes, the pelvic bones are quite unconnected with the skeleton. From this freedom of the posterior members in fishes, they are most frequently placed forward, near the head, where they afford least impediment to the lateral motions of the vertebral column. The long phalanges of the feet (81, 82,) are attached directly to the pelvic bones, there being seldom a trace of the intermediate bones of the legs developed in this class, where they are not required either to give support to the trunk, or mobility to the feet.

In the plagiostome cartilaginous fishes, the highest animals of this class, the ribs and the spinous processes of the vertebræ of the trunk, are as little developed as in amphibia, many of the anterior vertebræ (*e*,) of the trunk, are often anchylosed, and the whole bones of the cranium are united into a single piece, as seen in the skeleton of the common skate, *raia betis*, (Fig. 32.) The skull (*a*,) is of great size, with tough, thick, cartilaginous parietes; it is filled chiefly with the soft, glary, arachnoid tissue, and contains within the thickness of the temporal bone

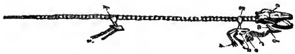
FIG. 32.



the whole of the internal ear. From each side of the head there passes down a short, round, moveable piece (*b*,) in the situation of the tympanic bone, which supports the lower jaw (*d*,) and the moveable, free upper jaw (*c*,) both covered closely with small teeth, like mosaic work. The scapular arch (*f*,) is fixed to the anterior, thick, anchylosed portion (*e*,) of the vertebral column, and the bones of the arms are also anchylosed together, and to this scapular arch. This fish lies at the bottom without an air-bag; its motions therefore in swimming being chiefly vertical, its hands (*g*, *g*,) are very large, and extended nearly round the whole trunk, from the point of the nose to the pelvic arch (*h*.) In the large hands of the rays and sharks, there are not only very numerous fingers or rays, but each finger (*g*,) is divided into a variable number of short, cylindrical phalanges, slightly dilated at their points of contact. The pelvic arch (*h*,) is generally very perfect in the plagiostome chondropterygii, and presents the rudiments of the three ordinary constituent bones, the ilium, the ischium, and the pubis, on each side; the two pubic bones united form a band passing transversely before the anus, the iliac bones ascend tapering to near the sides of the column, and the ischium on each side passes backwards. The feet are less than the hands, and consist of toes (*i*, *i*,) which are shorter, less numerous, and less divided than the fingers, (*g*.) The great size of the hand is the more required in the rays, from the smallness of the tail (*k*,) rendering it almost useless as an organ of motion. In the sword-fish, and in the saw-fish, the upper jaw bones, the vomer, and the nasal bones form a long projecting weapon of offence extending from the face above the free intermaxillaries, which bound the upper part of the mouth. The orbits are prolonged laterally to a great distance in the *zyæna*, or hammer-headed shark, so as to give a pedunculated appearance to the eyes. From the softness of the skeleton in the cartilaginous fishes, the mouth, and especially the lower jaw, is very short, and often extended much transversely; and for the same reason, these animals have numerous rows of teeth prepared to supply the places of those which are successively lost, as in the sharks, or have their jaws covered, as in the rays, with a continuous compact layer of small permanent teeth.

XX. *Amphibia.*—The amphibious or batrachian animals commence their career as fishes, with one auricle and one ventricle, and breathing by means of gills which in many are retained through life, but in their adult state they acquire a pulmonic respiration, and a pulmonic auricle of the heart, and this early aquatic life and subsequent metamorphosis affect the whole condition of the skeleton, and the forms of the several bones. The skeletons of the amphibia come nearest to those of fishes in the imperfect ossification, and the thin, diaphanous, elastic character of the bones, in the loose condition of the bones of the face, and in the imperfect development of the ribs. The perennibranchiate amphibia, and the tadpoles of the caducibranchiate species, present the softest and the most detached condition of the bones, and the most fish-like form of the whole skeleton. Their vertebral column is prolonged backwards to a great extent, as an organ of motion; their arms and legs are wanting, or are very imperfectly developed, and their os hyoides, like that of a fish, supports a variable number of branchial arches, as seen in the annexed figure of the skeleton of the *proteus anguinus* (Fig. 33.) The ver-

FIG. 33.



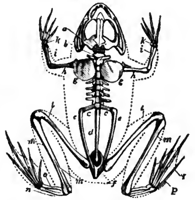
tebræ here have the bodies terminated before and behind by concave surfaces, as in fishes, and all the processes of these vertebræ are short, to allow of extensive motion, especially in a lateral direction. There is no sacrum, and the pelvic (*k*,) and scapular (*g*,) arches are as free as in fishes. A few small detached points of bone at the ends of the transverse processes of some of the anterior dorsal vertebræ are the only ribs here developed; and in this, as in many other characters, the proteus and the siren resemble the sharks. The parietal (*e*,) and the frontal bones are long and separate, the tympanic bone is long and moveable. The wide inferior jaws, the long intermaxillaries, and the loose upper jaw-bones are provided with sharp, recurved, conical teeth. The body (*b*,) and

cornua (*a*,) of the os hyoides are proportionally large, and support the three branchial arches (*c*,) on each side to which the permanent gills (*d*,) are attached. The flat dorsal portion of the scapula (*g*,) is thin and cartilaginous, and the coracoid pieces (*f*,) meet in front by broad extended edges. There are only three toes (*h*,) developed on the fore feet, the two inner consisting of three phalanges, and the outer of two ; and on the hind feet there are only two toes (*i*,) each consisting of three bones. The expanded, cartilaginous, iliac bones (*k*,) extend upwards to the sides of the vertebral column, as in the plagiostome fishes, without being attached to a sacrum, and the pubic bones unite with each other and with the ischia, to form a transverse anterior band for the support of the small legs. The condition of all parts of the skeleton is nearly the same in the *siren lacertina*, where the prolonged fish-like vertebral column has still greater freedom of motion from the entire want of legs and a pelvic arch ; the spinous processes of the vertebæ are more elevated, the coracoid bones meet by a longer surface, the hands have four toes, there are four branchial arches on each side : the body and cornua of the os hyoides are very large, and the tympanic and intermaxillary bones are as moveable as in a fish. The ribs are developed to a greater extent in the land salamander, where they have the form of straight tapering spines extending from the transverse processes of all the vertebræ of the trunk. The arms and legs which here support the trunk in a lighter medium than in the former animals, have all their bones larger and stronger, and have four toes before and behind. The whole bones of the skull and face are more fixed in their articulations, and the pelvic arch is more connected with the sides of the vertebral column, but without forming a sacrum.

It is however in the anurous amphibia, as the common frog, (Fig. 34.) that we find the most solid and fixed condition of all the bones, and the nearest approach to reptiles and higher classes in the structure of the different parts of the skeleton. The vertebræ of the tadpole are formed like those of a fish, with two cup-like cavities, but by the ossification and anchylosis of the intervertebral soft substance, it becomes fixed to the posterior end of the

body of each vertebra, so as to change their forms almost to those of reptiles. A great portion of their vertebral column, and of their os hyoides, and their branchial arches become absorbed, their legs and arms become developed, and many of the coccygeal vertebræ unite to form a single piece; so that these anurous highest kinds of amphibia pass through the inferior forms of their class before arriving at their perfect state. There are nine vertebræ in the frog (Fig. 34.) the first of which (*b*,) has a double articular surface, like two condyloid depressions for the two prominent condyles formed by the body of the occipital bone (*a*,) and this atlas is without transverse processes. The bodies of the succeeding vertebræ terminate posteriorly by slightly convex surfaces, and anteriorly by corresponding depressions, and the transverse processes are long, but irregular in their forms and magnitude. There are no ribs, and the pelvic arch is moveably connected with the ends of the transverse processes of the last or ninth vertebra (*c*, *c*.) This single vertebra forms, therefore, a true sacrum, and the succeeding coccygeal vertebræ (*d*,) are anchylosed into a single unperforated bone, slightly grooved at its commencement, running along the dorsal part of the pelvis, and entirely concealed within this part of the trunk. The two iliac bones (*e*, *e*,) long, cylindrical, and slightly curved, extend backwards from the sides of the sacrum (*c*, *c*,) to the ossa ischii (*f*,) behind, and the small pubic bones in front; and these three bones, united by sutures, form on each side of this compressed terminal part (*f*,) of the pelvis, the cotyloid cavity for the reception of the head of the femur. The legs are here very large, both for leaping and swimming. The long femur (*l*,) is succeeded by another long single bone (*m*, *m*,) the grooved

FIG. 34.



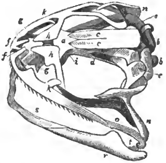
surface of which shows it to be formed of the tibia and fibula anchylosed together. To this succeeds a lengthened astragulus and calcaneum (*n*,) then three very minute cuneiform bones of the tarsus, and then the lengthened bones of the meta-tarsus and the phalanges of the five toes (*o*.) The humeri (*h*, *h*,) are comparatively short, strong, and slightly bent; the radius and the ulna (*i*, *i*,) are anchylosed like the tibia and fibula, and the six small carpal bones (*k*, *k*,) are succeeded by four long meta-carpal bones, the phalanges of four fingers, and a small rudiment internally of a fifth. The scapular apparatus (Fig. 35,) for the support of the arms is here very complete, and also the sternum, although there are no ribs to reach it. The posterior curved portions (*i*, *i*,) of the scapulæ, are thin and cartilaginous, as in many fishes and reptiles, and the anterior parts (*f*, *f*,) which chiefly contribute to the formation of the glenoid cavity (*k*, *k*,) for the head of the humerus is strong, and ossified. From the glenoid cavity, on each side, proceeds inwards the coracoid bone (*e*, *e*,) which expands as it reaches the sternum (*d*.) Above the two coracoid bones, (*e*, *e*,) are the two slender clavicles (*c*, *c*,) which also proceed from the glenoid cavities to the sternum, and leave a considerable vacant space between them and the coracoid bones. The anterior (*a*,) and the posterior (*h*,) portions of the sternum are thin, flexible, cartilaginous laminæ, and the intermediate parts are ossified and strong, for the insertion of muscles, the support of the scapular arch, and the protection of the fore part of the trunk. The upper thin portion (*a*,) appears to consist of the two *epi-sternal* pieces, the next part (*b*,) of the two *hyosternal* elements, the next (*d*,) the single *ento-sternal*, to which both the clavicles and coracoid bones are attached; the next (*g*,) the two *hypo-sternal* elements, and the inferior, thin, cartilaginous, terminal piece (*h*,) the two united *xiphisternal* elements which usually terminate this bone.

FIG. 35.

The bones of the head, even in the highest of the caducibranchiate amphibia, are still as loosely united together as in most of the osseous fishes, as is seen in the skull of the common frog, *rana esculenta*, (Fig. 36.) The occipital bone

has its basilar part divided by a vertical suture, and is securely united to the atlas by two prominent condyles (*b, b,*) belonging to that portion of the bone. The parietals (*c, c,*) are long, narrow, nearly separated by a sagittal suture, and extend forward over a large portion of this lengthened narrow cranium, as we see also in ophidian and saurian reptiles. The sphenoid bone has also a very lengthened form along the base of the skull, as in fishes. On the fore part of

FIG. 36.

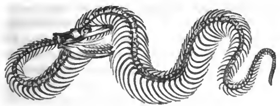


the skull are the two posterior frontals (*a,*) separate in the young frogs, but united into a single bone extended between the parietals (*c, c,*) and the two anterior frontals (*h, h,*) which extend laterally to the two pterygoid, and the two upper jaw-bones (*k, k.*) The two intermaxillary bones (*f, f,*) the two upper jaws (*k, k,*) and two bones behind these, regarded as divisions of the vomer, are provided with small, sharp, recurved conical teeth, although none are found opposed to them in the lower jaw. The slender jugal bone (*o,*) is extended from the upper jaw bone backwards and downwards to the lower end of the long tympanic (*n,*) which is here moveable, as in most oviparous vertebrata. The tympanic bone (*n,*) here, as in most of the lower vertebrata, sends down a condyloid process to be articulated with a glenoid cavity (*t,*) on the back part of the lower jaw. The lower jaw is divided at the symphisis, and each lateral portion consists of an anterior (*s,*) a middle (*r,*) and a posterior (*t,*) piece, which extend to a great distance transversely, and are entirely destitute of teeth, although there are teeth in the lower jaw of the salamander and the proteus. As we proceed upwards through the vertebrated classes, the teeth become more circumscribed in their number and in their distribution over the parietes of the mouth, till we find them confined to a single row disposed along the upper and lower jaws. We thus observe in the adult anurous amphibia a greater consolidation of the whole texture of the bones,

and of the different parts of the skeleton than we find in fishes; and many elements originally separate have become anchylosed together, which conditions prepare the solid frame-work to support and carry the whole fabric through a much rarer medium than the dense water in which they commenced their career, and in which the fishes permanently reside.

XXI. *Reptilia.*—The bones of serpents are more compact, white, dense, and elastic than those of the other orders of reptiles; but their skeleton is the most deficient in its parts, consisting almost solely of the vertebral column without legs or arms, or a pelvic or scapular arch, or even a sternum to connect the ribs, as seen in the skeleton of the *boa constrictor*, (Fig. 37.) With this simple skeleton they are able to creep quickly on the ground, to combat with

FIG. 37.

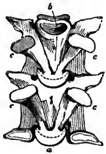


their prey, to climb trees, to spring into the air, and to swim rivers and lakes. The ribs are developed from the sides of the vertebral column from the atlas to the anus, and the transverse processes continue to extend to a considerable length from the sides of many of the anterior coccygeal vertebræ. From the absence of a sternum in front, and the free articulation of the ribs with the ends of the transverse processes of the vertebræ, the ribs possess the means of extensive motion, and cause the transverse scuta on the lower surface of the abdomen to move like so many feet. The ribs of serpents are tubular, with thin compact parietes, and containing a soft cancellated structure in their interior, by which they possess great elasticity and strength. They are narrow, and compressed from before backwards, strong and broad at their head and neck, and taper regularly to their free ventral extremity, where they generally terminate

with a thin, flexible, cartilaginous prolongation. Their head presents a broad, arched, concave surface, to form a secure and free articulation with the rounded, prominent, transverse processes of the vertebræ. The broad and long transverse processes in the coccygeal region of the column, cover a long pelvic cavity in the male, in which the two divisions of the penis are lodged in their retracted state. As the ribs extend along the whole sides of the trunk, from the head to the anus, there are no cervical nor lumbar vertebræ ; and as there are no legs nor pelvis, there is no sacrum.

The vertebræ are here more numerous than in any other class of animals, so that there is great flexibility of the whole body, and their articulations are remarkably secure from the extent and the number of the articular surfaces between each pair of vertebræ. All the processes of these vertebræ are short, to admit of greater freedom of motion, excepting the four articular processes, which are very broad, to give a greater security of attachment ; and hence the quadrangular or cubical form presented by the vertebræ of serpents,as seen in the front view of those of the *boa constrictor*, (Fig. 38.) The lower part of the body of each vertebra terminates in a large, oblique, hemispherical convexity (*a*,) smooth on the surface, and covered with a thin layer of cartilage. This prominent end of the vertebra is received into a corresponding deep, cup-like cavity (*b*,) with sharp margins, and lined with cartilage, at the anterior end of the next succeeding vertebra, and this regular ball-and-socket form of articulation is continued through the whole vertebral column. These articulations are secured by strong capsular ligaments, and lubricated by a copious secretion of synovia. The two anterior, and the two posterior articular processes present broad flat surfaces, extended transversely, those of the anterior vertebra passing over those of the next succeeding vertebra, as in other classes. The shortness of the transverse processes (Fig. 38. *c*, *c*, *c*, *c*,) allows of a greater extent of lateral motion in the column, and, for the same reason, the vertebral foramina for the

FIG. 38.

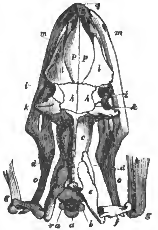


spinal chord are most dilated before and behind in that direction. These very short, strong, transverse processes have each a large, convex, prominent, articular surface, extending downwards, inwards, and a little forwards, which is received into the articular concavity of the head of the rib. From the four articular processes of the vertebræ extending to a great distance laterally in a straight and horizontal direction, they give great extent and safety to those lateral motions which are chiefly required in the trunk of serpents. The bodies of the dorsal vertebræ are carinated below, and have a narrow contracted neck at the base of the posterior, hemispherical, articular tubercle. The laminæ are here very strong, and evasated before and behind, to enlarge the two ends of each vertebral foramen, that the spinal chord may not be pressed upon during the motions of the vertebræ. The spinous processes are short, strong, and broad, from before backwards, so as to afford a strong attachment to the muscles, without interfering with the motions of the vertebræ.

In the skulls of reptiles, as in fishes and amphibia, we still find the cranial vertebræ disposed in the same straight line as those of the rest of the column, and most of the elements of the cranial bones still remain separate through life. The serpents and lizards present the most detached condition of all these cranial bones met with in the class of reptiles; the crocodilian animals, and the chelonia have them the most firmly united by sutures. This loose state of the bones of the head is the more necessary in serpents, which, from the want of arms and legs to hold down their prey, and assist in its subdivision, are compelled to swallow it entire. The annexed figure of the skull of the *python* (Fig. 39.) shows the most common disposition and form of the bones of the head of serpents. The basilar portion (*a*,) of the occipital bone remains distinctly isolated from the two lateral condyloid pieces (*a**,) and these three elements form the large, transversely elongated, occipital condyle, the basilar element forming the greater portion of it. The superior or median occipital (*b*,) is here small and detached, as in the saurian reptiles. The parietal bones (*c, c*,) are long, and anchylosed together along the median line, to afford a solid unyielding covering to the lengthened brain

beneath them. These two bones are thus early united in most other reptiles, in all birds, and in the greater number even of the mammalia, although they are separate in the normal form of the human skull. This condition of the two parietals is the more required in serpents, from the loose state of most of the other bones of the head, and the exposure of these animals to the trampling of quadrupeds, and other dangers while they lie concealed in their natural haunts. The anchylosis of the two parietals gives greater security to the strong temporal muscles of these animals, as in other classes, where this solidity of attachment is required. From the length, and the loose attachment of the squamous portion (*e*,) of the temporal bone to the parietals, the tympanic bone (*f*,) and consequently the lower jaw (*g*,) has much greater extent of motion in a lateral direction. The two anterior (*i*, *i*,) the two middle (*h*, *h*,) and the two posterior (*k*, *k*,) frontals remain detached, and form, as in other reptiles, the greater portion of the front of the skull. The great breadth of the two lachrymal (*l*, *l*,) and of the two nasal (*p*, *p*,) bones corresponds with the general flat and broad form of the head of serpents. The two upper jaw-bones (*m*, *m*,) and the two intermaxillaries (*q*,) are separate and quite moveable on the surrounding bones; and the two palatines are also moveable and long, and support the most permanent teeth of these animals. The two sides of the lower jaw are quite detached from each other, and freely moveable at the symphesis, and the pieces of which it is composed are also moveable. This freedom of motion of the lower jaw (*g*, *g*,) extends through the long tympanic (*f*, *f*,) and squamous (*e*, *e*,) elements of the temporal bone to its more fixed petrous portion (*d*,) so that the mouth is here capable of extraordinary dilation, to transmit through its cavity entire prey, which the serpents have not the means of dividing.

FIG. 39.

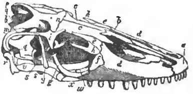


Their teeth are organs of prehension, and not of mastication; they are conical, slender, sharp, recurved, osseous spines, covered with enamel, with very shallow alveoli, placed along the upper and lower jaws, the intermaxillaries, and the palatine bones. The upper jaw bones in the poisonous snakes terminate abruptly in a round peduncle below and before the orbits, which supports the tubular poison-fang, and the small teeth which usually accompany it upon each side of the head.

The saurian reptiles have the skeleton more complete than the serpents, as they possess a complex sternum, and scapular apparatus, a fixed pelvis, together with atlantal and sacral extremities; but the transition from the one form is very gradual from the serpents with the rudiments of pelvic and scapular bones, to the bimanous and the biped lizards; and from these to the regular saurians with fore feet, and to the more solid and complete forms of the skeleton presented by the crocodilian reptiles. By the increased development of all the processes of the vertebral column, we perceive the preparation for more solidity in the articulations, and more limited motions in that part of the skeleton, the locomotion is now to be effected by the arms and legs, and not by the vertebral column, as in most of the lower vertebrata. The large bones of the sauria present a coarse fibrous structure, contain a large proportion of animal matter, and have a cancellated loose texture internally, where we find tubular cavities in the birds and mammalia. The bodies of the vertebræ, in the lacertine sauria, preserve the ball-and-socket joint throughout the column; but these parts of the vertebræ are more compressed, and the articulations are more oblique than in the serpents. From the necessity for supporting the trunk upon the legs, the pelvis is united firmly to a sacrum, consisting generally of only two enlarged vertebræ. The bodies of the vertebræ are generally more lengthened, and the articular processes more extended in a longitudinal direction than in the serpents. There are two concave surfaces of the bodies of the vertebræ, of the gecko, as in fishes and tadpoles, and in the ichthyosaurus. In the coccygeal vertebræ, besides the lengthened superior spinous process, and the two transverse processes, there are inferior spinous processes, which are interposed between

the bodies of the vertebræ, and by forming a small arch they give protection to the large blood-vessels of the tail, which is generally a thick muscular continuation of the trunk. There are false ribs in front of the true, as well as behind them, as we see also in birds, and in some mammalia; and there are generally about seven cervical vertebræ, as in quadrupeds. The head is extended forwards in the same straight line with the vertebral column, as in the inferior vertebrated classes. As in these inferior classes also we observe the bones of the head of the lacertine reptiles remarkably loose and moveable in their articulations, as seen in this figure of the skull of the *lacerta nilotica*, Cuv. (Fig. 40.) The occipital bone, as in the serpents, has its transversely elongated condyle composed chiefly of the basilar portion of that bone. Exterior to the two condyloid pieces, (*q*, *q*,) of the occipital are the long slender, curved, squamous (*l*,) and mastoid (*m*,) elements of the temporal bone, almost as loose as in serpents, and giving support to the short and moveable tympanic portion (*r*,) of that bone to which the articular portion of the lower jaw is attached. The two parietals (*n*,) are anchylosed together, as in serpents, and support the posterior edges of the two middle frontals (*c*, *c*.) The anterior (*e*, *e*,) and the posterior (*i*, *i*,) frontals form the upper boundary of the large bird-like orbits. The petrous portion (*p*, *p*,) of the temporal bone is here the largest and strongest element, extending forwards to the sphenoid (*s*,) and backwards to the very long and slender squamous (*l*,) and mastoid (*m*,) portions. The two lachrymal bones (*f*, *f*,) extend less over the face than in serpents, and between them and the anterior frontals (*e*, *e*,) are the superciliary bones (*h*, *h*,) as in birds. The upper jaw bones (*d*, *d*,) and the intermaxillaries (*a*,) are more fixed than in the former order of reptiles, and these intermaxillaries are often anchylosed together, as are also the two narrow lengthened nasal bones (*b*.) The large inferior turbinated bones are here exposed, from the small-

FIG. 40.



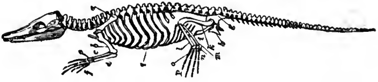
ness of the anchylosed nasal bone ; the palatine bones are more fixed than in serpents, and are destitute of teeth, and the two pterygoid bones (*v*,) extend, as in serpents, backwards and outwards to the tympanic (*r*.) The lower jaw is divided at the symphysis, and consists on each side of six pieces, of which the anterior or dental portion is the largest, and the prehensile teeth are here as loosely attached by their expanded base to the alveolar flat surface of the jaw, as in serpents, protected at their bases by an outer, and sometimes an interior ridge of the dental bone, but not lodged in separate alveoli. The osseous bases of these teeth in the lizards often anchylose to the surface of the jaws, as in fishes, and the new teeth generally rise up on the inner side of the base of the old or of the lost, and not in the interior of their cavity, as they do in the crocodiles.

The ribs of lizards are for the most part rounded and slender, and without the tubercle so much developed in quadrupeds and birds. The scapula is thin, broad, and curved ; the coracoid also terminates in front by a very broad curved margin by which it unites to the large ento-sternal piece. The acromion is a distinct bone of very variable size and form, and the clavicles are anchylosed and extended in form of a cross along the fore part of the sternum. The sternal elements are thin, soft, and extended transversely, and have chiefly the ento-sternal enlarged and strong, as in birds. The humerus, also as in birds, is much expanded at its upper and lower extremities, the ulna is much stronger than the radius, and distant from it, especially at the carpus. There are nine bones in the carpus, as in tortoises. The three pelvic bones contribute to the formation of the cotyloid cavity for the head of the femur. The expanded edges of the ossa pubis, and ossa ischii meet and form a lengthened symphysis on the median line in front, and the spine of the iliac bones is extended, not forwards, as in higher classes, but backwards along each side of the sacrum towards the coccygeal vertebræ. The head of the femur is compressed, and bent forward, and the great trochanter is also compressed and turned towards the tibia. The patella is always small, the tibia short, strong, thick at its ends, and much curved at its fibular margin. The fibula

is always slender in its middle, apart from the tibia, and thickened at its ends. There are four bones of the tarsus, as in the crocodiles, and the bones of the meta-tarsus like those of the meta-carpus, and the phalanges of the toes and fingers are lengthened to form prehensile flexible members for climbing in these land forms of saurian reptiles.

The skeleton of the nilotic crocodiles (Fig. 41.) like that of the gavials and alligators, belongs to reptiles destined to swim through the water by the lateral movements of a

FIG. 41.



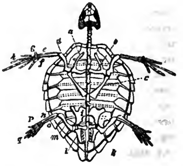
powerful muscular vertical tail, and also by the impulse of long webbed feet. Their long bones are coarse in texture, and filled internally with a loose osseous structure containing a thin oily marrow. The whole bones of the head are firmly united together by sutures, so as to admit of no motion on each other. The parietals are anchylosed together, the tympanic bone is fixed by sutures to the other parts of the temporal, and forms a prominent condyle for the lower jaw; the median frontals are anchylosed together, but the two anterior and the two posterior frontals are detached. The large malar bones, continued from the lachrymal to the temporals, form the outer boundary of the orbits. The nasal bones extend between the upper jaw bones to the intermaxillaries in the crocodiles and alligators; but in the gavials they extend only to a short distance along the muzzle, so that that lengthened part of the face is not weakened by so many sutures. The whole of the rounded termination of the upper jaw is formed by the intermaxillaries which surround the nasal aperture. The teeth of these crocodilian sauria are hollow striated cones, which contain within their cavity the new teeth which are to

succeed them, and they are firmly lodged in deep alveoli. The vertebræ of the crocodilian animals have for the most part a lengthened narrow body, concave before and convex behind, as in other reptiles. The transverse processes of the cervical vertebræ are very broad and long, and detached like ribs, and impede the lateral movements while they encrease the muscular power of the neck, for carrying off and struggling with their large prey. There are two pairs of false ribs before, and two pairs behind the true ribs. The true ribs have a strong attachment, by their lengthened head and prominent tubercle, to the sides of the bodies of the vertebræ, and the extremities of their transverse processes. The sternal ribs (Fig. 41. *q*,) are ossified, and similar ossified ribs are continued along the fore part of the abdomen to the pubis. The scapula and the coracoid bone are separate, more lengthened and narrow than in the lizards, and more thick and solid. The clavicular bone of the lizards is here extended forward below the neck, and the ento- and xiphi-sternal portions are most developed in the sternum. The three pelvic bones are more loose than in other saurians. The short expanded iliac bones (*g*,) are attached to two broad sacral vertebræ. The ossa ischii (*h*,) meet in front, and form an expanded symphysis, like most pubic bones; the pubic bones (*i*,) are the most slender, and extend forward from the cotyloid cavity, converging, but without meeting to form a symphysis. The humerus (*b*,) and the femur (*k*,) are both curved in the direction best calculated to give effect to their movements in the water. The radius (*c*,) and the ulna (*d*,) as well as the tibia (*l*,) and the fibula (*m*,) are here strong and separate to their extremities, leaving a large interosseous space, and forming a broad and highly moveable articulation at the carpus (*e*,) and the tarsus (*n*.) The bones of the meta-carpus, (*f*,) and meta-tarsus (*o*,) and the phalanges of the fingers and toes, are long and securely articulated at both ends for their double use in the water and on land.

The chelonian reptiles differ from the sauria in having the ribs immoveable, and from the serpents in having arms and legs; but their skeleton retains the ordinary conditions of that of the class in the coarse fibrous texture of the bones, in the want of continuous cavities in the long bones, and in the permanent separation of the cranial and other osseous

elements. The cervical and the coccygeal vertebræ are those which alone are moveable, and nearly throughout the whole column their bodies present the usual concavity at their anterior end, and convex termination behind. The vertebræ of the trunk have a lengthened form, as seen in the *caretta caouana* (Fig. 42,) and their bodies, their laminæ, and their spinous processes are connected only by sutures. There are eight pairs of ribs united to each other by sutures, and attached between the bodies of the vertebræ. By their union with each other, and with the expanded spinous processes of the dorsal vertebræ, they form the upper shield or carapace. The lower shield, or plastron, is formed by the nine elements of the sternum, and these two parts are attached to each other, by the sternal appendices (*k*,) which admit of motion in the turtles. The scapulæ (*a*,) are generally cylindrical bones more or less lengthened, extending from the sides of the first pair of dorsal vertebræ to the glenoid cavity for the head of the humerus, and they are anchylosed to the coracoid bones (*b*,) which converge and have their free ends attached to the interior of the ento-sternal bone. The two clavicles (*c*,) are separated by suture from the scapulæ, and are generally flat and expanded at their free extremities, which extend backward and inwards. The vertebræ composing the sacrum are anchylosed to each other, and from their sides extend downwards and outwards two short, cylindrical, iliac bones (*l*,) which enter into the formation of the cotyloid cavity, like the two other pelvic bones, the ossa ischii, which meet in front, as in other reptiles, and the two broad expanded pubic bones (*i*,) which generally send upwards obliquely a large process like the marsupial bones of mammalia. In the sternum of the land tortoise (Fig. 43. 1.) the nine elements are firmly united to each other by sutures, and also in the same manner to the sternal

FIG. 42.



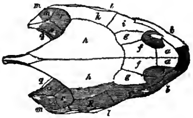
ribs. The two epi-sternal pieces (*a, a*,) form the anterior margin, and unite behind with the ento-sternal piece (*b*,) which is single on the median plane, and with the two hyo-sternal pieces (*c, c*,) which extend laterally to unite with the sternal ribs. The two hyposternal elements (*d, d*,) are large and broad, like the hyo-sternal, and also like them unite laterally with the sternal ribs. The two xiphi-sternal pieces (*e, e*,) are united to each other, and to the hypo-sternals by serrated sutures, and form the whole posterior termination of the plastron or lower shield. In the sternum of the turtles (Fig. 43, 2.) nearly all these elements are moveable on each other, and at their points of contact with the sternal ribs. The two epi-sternals (*a, a*,) taper laterally to a point, and are not united by sutures; the ento-sternal (*b*,) has its whole posterior portion free, and although the hyo- (*c, c*,) and hypo- (*d, d*,) sternals on each side are united together by firm sutures, they have moveable articulations on their lateral margins. The xiphi-sternals (*e, e*,) are here freely moveable, and taper to a point posteriorly, like the two epi-sternals. So that there is great solidity in the whole plastron, as in the whole carapace of the land animals to resist pressure, to which they are much exposed, and they form a dense frame-work for their muscular movements on the land, while there is great mobility in the sternal apparatus of the aquatic species, for the extensive respiration which they require in that dense element.

FIG. 43.

The bones of the head in the chelonia, like those of the crocodiles, are immoveably united by sutures, and in place of teeth there are strong cutting, horny plates covering the alveolar surface of the jaws, as in birds. The occipital condyle is composed of three distinct facets, formed by the basilar and the two condyloid portions of that bone. The superior median portion of the occipital extends backwards in form of a long spinous process, as in most osseous fishes, for the attachment of the powerful muscles of the neck. The two parietal bones are separate, and form in the tortoises of the land an elevated longitudinal ridge, which is continued forwards over the cranium to the frontal

bone. In the marine turtles, and in the fresh-water emydes, as seen in the skull of the *emys expansa* (Fig. 44. *h, h,*) the parietal bones rise upwards on the median line of the head, and extend laterally over the temporal fossa. The tympanic bones are large, fixed by suture as in the crocodiles, and extend downwards to form a condyle for the articular cavity of the lower jaw. The two posterior (*g, g,*) and the two middle (*f,f,*) frontals bound the orbits above, and the two malar bones (*i, i,*) behind. The two anterior frontals (*a, a,*) bound the orbits in front, and expand over the nasal aperture, like nasal bones. The intermaxillaries are narrow, vertical, with an extensive palatine surface, and like the superior maxillaries, they present a sharp alveolar edge, which is covered with the cutting, horny, superior mandible. Behind the two jugal bones (*i, i,*) are the expanded squamous portions (*k, k,*) of the temporals, and behind these the two long, descending, mastoid bones (*m, m.*) Anterior to the mastoid bones (*m, m,*) are the upper portions of the tympanic bones (*r, r.*) Two portions (*o, o,*) detached from the condyloid elements (*q, q,*) of the occipitals, are termed exterior occipitals by Cuvier. The ossicula auditus are anchylosed together, as in many of the lower vertebrata. The symphysis of the lower jaw is anchylosed at a very early period of growth, as in birds. From the importance of the os hyoides in the motions of respiration in these animals, where the ribs are fixed, its body and cornua are very large and strong.

FIG. 44.



The arms of the tortoise are fixed in a state of pronation, to strengthen them for the support of the heavy trunk; and, like those of the legs, all their bones are short and massive in their proportions. The humerus is much bent, the radius and ulna short, strong, and with a very broad articular surface at the carpus, and the succeeding bones of the hands are short and almost cubical, for support and for digging, like those of the mole. The same proportions are

observed in the bones of the posterior extremities, but the outer toe is generally quite rudimentary, while the five fingers are more equally developed on the hands. In the aquatic chelonia the bones of the extremities have a more lengthened, straight, and slender form, and especially of the anterior extremities (Fig. 42,) which are much more developed than the posterior. They are also more flat and compressed, and less moveable on each other ; so that they form a near approach to the condition of these bones in the arms of a cetaceous animal, or in the arms and legs of an ichthyosaurus and a plesiosaurus. The humerus (Fig. 42. *d*,) the radius (*e*,) and the ulna (*f*,) the bones of the carpus (*g*,) and even those of the meta-carpus, and the phalanges of the fingers (*h*,) partake of this lengthened and flattened form, the best adapted for progressive motion through the water. And we observe the same character, though to a less extent, in the femur (*m*,) the tibia (*n*,) and the fibula (*o*,) and in the bones of the tarsus (*p*,) the meta-tarsus, and the phalanges of the toes (*q*,) where all the parts are shorter than the corresponding bones of the anterior extremities.

XXII. *Aves*.—The bones of birds are more compact, white, dense, and brittle than those of any other class ; they have thinner parietes, their internal cavities are proportionally larger, and for the most part they contain air in place of marrow. From the great extent of their respiration, and the consequent encreased energy of all their functions, ossification proceeds in birds to the greatest extent, not only in the consolidation of the several pieces of the skeleton, but in the anchylosis of the separate elements and separate bones with each other, throughout the skeleton, and in the consolidation, by phosphate of lime, of cartilaginous and tendinous parts, not ossified in other classes. In the young state the bones of birds are filled with a thin serous marrow, like those of reptiles, and this is displaced by the admission of air during growth, to a very variable extent, in the different orders of this class, the air being admitted most extensively in the high flying rapacious birds, and least in the heavy swimming palmipeds. There is greater uniformity in the skeleton of this, than of the other vertebrated classes. The arms are here adapted solely for flight, the legs for support, and the head and neck are long and

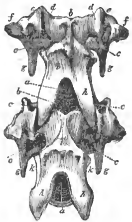
extensively moveable, as organs of prehension; hence the peculiar forms presented by these regions of the skeleton in birds, as seen in the skeleton of the griffon vulture, *vultur fulvus*, (Fig. 45.) As the body is supported wholly on the legs, the toes extend to a great length, to afford a broad base, the legs are placed forwards upon the sides of the pelvis, the trunk is inclined backwards upon these organs of support; the neck and head are proportionally elongated, to reach the food upon the ground, and the arms and hands are folded longitudinally along the sides of the trunk, as in the bats. The trunk of birds is almost as fixed as that of a tortoise, to give strength to the muscles employed in flight, and the vertebræ of the neck and tail are almost alone moveable. The rapid ossification and anchylosis here affects not only the bones of the skull, but the whole bones of the pelvis, the lower jaw, the scapular arch, the clavicles, and the sternum. This tendency to ossification affects the sterno-costal cartilages, the tendons of the muscles of the legs, the sclerotic coat of the eye, the rings of the trachea, and the inferior larynx.

FIG. 45.

The vertebræ of the neck are always more numerous than in the mammalia, and are sometimes more than three times the number common to that class. They have their articular surfaces so directed that the neck is naturally concave in front at the upper part, and convex in front at the lower part, presenting more or less of that sigmoid curviture, which is so conspicuous in the long-necked birds. The oblique processes, as seen in those of the swan, (Fig. 46. *h*, *h*,) are generally long, narrow, and diverging, admitting with safety of very extensive motion. The spinous processes (*i*, *i*,) are very short, to offer no obstruction to the movements of the neck. The transverse processes (*f*, *f*,)

are short, and strong, and give passage to a large foramen (*c, c*,) on each side, for the vertebral arteries and nerves. The foramen for the spinal chord is dilated at its anterior and posterior extremity, in the direction of the greatest motion of the vertebræ, in order to protect from compression the spinal chord, and the nerves which enter it laterally. The posterior ends of the bodies of the vertebræ (*a, a*,) are narrow, convex, arched transversely, and received into a corresponding transverse groove on the anterior part of the body of the next succeeding vertebræ. The transverse processes are prolonged so far backwards (*g, g*,) as almost to form a continuous canal along the sides of the neck, for the protection of the enclosed large vertebral arteries, and the cervical portion of the sympathetic nerves. The forms of the processes, and of the articulations of the dorsal vertebræ are calculated by every means but by anchylosis to impede motion and to give solidity to that part of the trunk. The spinous processes of these vertebræ are developed forwards and backwards to such an extent that they come almost into contact with each other before and behind. The free ends of the transverse processes extend so much forwards and backwards that they commonly pass over each other in an imbricated manner, and prevent all lateral motion. And the anterior or sternal surface of the bodies of these vertebræ are often compressed, carinated, and extended downwards, like inferior spinous processes, which further impede motion. The dorsal vertebræ are often anchylosed together, like all the lumbar and sacral, to give greater solidity to the trunk, for the movements of flying. The lumbar vertebræ are most free in the ostrich ; in other birds they are anchylosed to each other and to the sacral, as the sacral are to each other and to the iliac bones; so that the different kinds of vertebræ in this region of the trunk are

FIG. 46.



almost indistinguishable from each other, and the sacral vertebræ are more numerous than in all other forms of vertebrata. The canal for the spinal chord in the middle of the sacrum, between the two cotyloid cavities, where the nerves of the posterior extremities commence, is very wide, and corresponds with the great inferior enlargement of the spinal chord at that place. In the intervals between the transverse processes of the sacral vertebræ are contained internally on each side the several unequal lobes of the kidneys. The coccygeal vertebræ are moveable and strong in birds, to support the plumage and muscles of this great and flexible organ of motion. They have long transverse processes, and spinous processes both above and below the bodies, and the last of the vertebræ (Fig. 45. *g*.) has a lengthened, compressed, crescentic form, to increase the extent of its lateral surfaces.

The lengthened form of the head in birds depends chiefly on the elongation of the jaws, and corresponds with the lengthened form of the neck, and the various manipulations and prehensile uses to which this part is applied. The cranium is short and broad, like that of most cetacea; it is bounded before by very large orbits, separated from each other only by a thin membranous partition, or by a thin plate of the sphenoid bone, and the bones which form it are anchylosed together, so that all traces of the coronal, sagittal, lamdoidal, squamous, and other sutures have here disappeared, as seen in the skull of the golden eagle, *falco fulvus* (Fig. 47.) The occipital (*a*,) the parietal (*b*,) the frontal (*c*,) and the temporal bones are for the most part thin, diaphanous, smooth externally and internally, like the surface of the cerebral hemisphere, and embrace a large lobed cerebellum, large optic lobes, and smooth hemispheres of the brain, which taper forwards to the ethmoid bone. The nasal (*f*,) and the superior maxillary bones (*g*,) are moveable on the frontals, sometimes by a distinct articulation, as in the parrots and

FIG. 47.

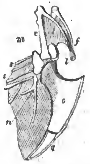
cockatoos, but most generally by means of the thin flexible condition of these bones at their line of junction; and by this the gape of birds is widened, to take in or seize bulky objects, which their toothless jaws and the form of their hands do not enable them to subdivide. The basilar part of the occipital bone is short, from the shortness of the cranical cavity, as in reptiles, amphibia, and cetacea, and it extends backwards in the form of a single, round, prominent condyle, by which greater extent of rotation is afforded to the head on the neck. The body of the sphenoid is lengthened, as in the inferior vertebrata, and the two pterygoid bones still remain permanently detached, extending laterally to the loose tympanic bones (*l*.) The tympanic element of the temporal bone, or the os quadratum (*l*,) is here freely moveable, as in fishes, amphibia, and most sauria; it sends downwards a convex, prominent, articular surface, for the attachment of the lower jaw, and is likewise attached to the long, slender, malar bone (*n*,) which forms the inferior boundary of the orbit, by which attachment it is enabled to push forwards and upwards the superior maxillary, and thus widen the mouth. The palatine bones are long, large, and detached, leaving a wide fissure between them; but the intermaxillaries are anchylosed to each other, and to the superior jaw bones, which are also united to each other. On the anterior part of the orbits, the large lachrymal bones (*e*,) and the small superciliary bones (*d*,) are detached, especially in the rapacious birds; and, notwithstanding the wide openings of the nostrils externally, the turbinated laminæ are small, soft, and cartilaginous; the olfactory nerves are transmitted through the back part of the large orbits to the nose, there being no perforation for these nerves in the thin cancellated structure of the ethmoid and sphenoid bones separating the orbits, and here filled with air. The diploe of the cranium, which is largely developed in nocturnal birds, as owls, is filled with air, like the bones of the trunk and of the extremities, which is admitted through the Eustachean tube, and the cavity of the tympanum; so that it encreases the intensity of sounds and the dimensions of the organs of hearing. No parts of the skeleton vary so much in birds, as the upper and lower jaws, according to the kind of food on which the different species subsist and

their modifications are therefore intimately connected with the general forms of the skeleton, and the living habits of the species. The upper bill is long and hooked in fishing birds, shorter in vultures, and still shorter in eagles and hawks. The jaws are long, straight, tapering, and pointed in herons and storks, shorter and slender in wood-peckers, and still more slender and pointed in insectivorous singing birds. They are long and curved in the ibises, and curlews, and humming birds, short, conical and strong in the gallinaceous and granivorous birds, and still shorter and stronger in the parrots and cockatoos, to break the hard nuts on which they feed. They are flat and depressed, and generally with serrated margins in the mallards, and ducks, and swans, flatter in the spoon-bills, and still broader in the pelicans. With these forms of the bills and jaws, correspond especially the forms of the digestive organs, and the claws of the feet, as the analogous parts correspond with the forms of the teeth in quadrupeds.

From the length and varied uses of the tongue in birds, the elements of the os hyoides are much extended longitudinally, especially its cornua, or cerato-hyal portions, which are often extended so far backwards that they rise upwards behind the occipital bone, and arch forwards over the skull. The lingual portions of the os hyoides, the basi-hyal, and the glosso-hyal elements are also lengthened, like the tongue and the whole face of these animals. There are in birds, as in the inferior vertebrated classes, and as in some of the mammalia, false ribs, anterior as well as posterior to the true ribs. The ribs are here broad and compressed, securely articulated to the vertebræ by their long head and long tubercle, and they have generally a process extending upwards and backwards from their posterior margin, especially those placed towards the middle of the trunk. At their vertebral extremity the ribs are compressed from before backwards, so as to present their sharp edge to the cavity of the trunk; and at their sternal end they are compressed in the opposite direction, so as to present their broad concave surface to the interior of the body. The sternal extremities of the true ribs are united by cartilage to the ends of the sternal ribs, or ossified sterno-costal cartilages ; and it is at this articulation that the most extensive motions

take place during respiration. The broad and thick anterior ends of the sternal ribs are received into deep articular cavities on the sides of the sternum, and principally of the hyo-sternal portions of that bone, and they move freely and securely in these sternal cavities. The sternum in birds, as in chelonia, covers the greater part of the anterior surface of the trunk, and presents, excepting in the strutheous birds, an elevated, median, longitudinal, external crest, which greatly extends the surface for the attachment of the pectoral muscles. Its elements are anchylosed together, like those of the cranium and pelvis in the adult; but at an early period the rudiments of nine elements can be detected in its composition, which are generally disposed as represented in that of the peacock, *pavo cristatus*, (Fig. 48,) although they vary much in their relative development in different species. The two epi-sternal pieces (*l*,) are small, compressed, anchylosed portions, which rise upwards between the two coracoid bones (*c*,) behind the united clavicles (*f*,) and are ossified to the upper edge of the large and long ento-sternal element (*o*,) which is the largest element of the sternum, and that which has to sustain almost the entire force of the pectoral muscles during flight. The ento-sternal piece (*o*,) forms the crest of the sternum, which is hollow and open above in many aquatic birds, to admit a turn of the trachea, and is thick and solid in the strongest rapacious birds; it admits air into its interior by apertures on its inner and upper part, and it receives the articular surfaces of the two coracoid bones (*c*,) at its upper edge. The two lateral portions (*m*,) which give attachment to the sternal ribs (*s*, *s*,) are the hyo-sternal elements, which are very large in the ostrich. Extending downwards and backwards from the posterior margin of the hyo-sternal element (*m*,) is a long narrow bone, generally bifurcated in the gallinaceous birds (*n*,) which is analogous to the hyposternal portion of this bone in the chelonian reptiles; it is more extensively developed in the water birds, and most of all in the raptorial species, where it forms a continuous piece with the lower end of the ento-sternal. The small

FIG. 48.



tapering terminal cartilage of the sternum, continued from the posterior end of the ento-sternal portion (*o*,) is composed of the two xiphi-sternal elements (*q*,) analagous to the xiphoid cartilage of the human sternum. The scapular arch is very strong in birds, to form a solid resisting fulcrum for the powerful movements of the humerus; and the magnitude and strength of these bones corresponds in the different species with the power of flight, or the resistance they have to oppose to the pectoral muscles on the one side, and the branchial on the other. The scapulæ (Fig. 49. *a*, *a*,) are long, curved, compressed bones, extending along the back, on each side of the dorsal vertebræ; they become more narrow and rounded as they approach the glenoid cavity, where they suddenly expand to enlarge that cavity (*b*,) and they are partially anchylosed at that place to the large and strong coracoid bones (*c*, *k*.) The two coracoid bones (*k*, *k*,) extend from the articular cavity (*c*,) for the head of the humerus downwards and inwards, to rest their broad expanded base (*i*,) in a deep groove on each side of the anterior margin of the ento-sternal bone. These coracoid bones almost alone resist the approximation of the humeri on the median plane, and their descent in the direction of the pectoralis major on each side, and they have generally more than double the thickness and strength of the scapulæ. The two clavicles (*d*, *d*,) descend converging from the upper or humeral ends of the coracoid bones (*c*,) and they are anchylosed together at their lower ends (*e*,) where they commonly present a flat compressed prominence (*f*,) connected by cartilage, by tendinous expansions, or sometimes by anchylosis, with the anterior projecting point of the crest of the sternum (*g*.) The clavicles are very thick and strong, and meet at an obtuse rounded angle in the most powerful of the rapacious birds, and are long, thin, and slender, and meet at an acute angle in the gallinaceous and other birds of feeble flight. In the ostrich the clavicles are very small and short, and disunited on the median

FIG. 49.

plane, as in mammalia. In the arm of the bird there is a great development of the proximate bones, which by their magnitude and strength are best able to withstand the resistance to which they are so frequently opposed, while the more delicate and the more distant bones of the hand are few and less perfectly developed. The humerus (Fig. 45. *e*,) has a broad, compressed, and curved head, the large articular surface of which plays freely in the shallow glenoid cavity formed by the scapular and coracoid bones. In the concavity at the back part of the head of the humerus, are the large apertures by which the air from the axillary cells gains admission into the capacious interior cavity of this bone. The distal extremity of the humerus is curved forwards, and presents a broad articular surface with a double condyle, on which chiefly rotates the large ulna (Fig. 45. *h*,) the radius being a more slender bone. The radius and the ulna are so articulated as to resist pronation and supination of the hand, these motions being partially admitted at the head of the humerus. The arm of the bird is fixed in a state of pronation, the position best suited to strike the air with effect, and the hand moves upon the arm, not in the common mode of flexion and extension, but by abduction and adduction. At the extremity of the radius (Fig. 50. *a*,) and the ulna (*b*,) there are two carpal bones (*c*, *d*,) which are succeeded by a single long metacarpal bone (*g*,) composed of three pieces anchylosed together. One of these pieces (*e*,) on the radial side of the hand is very short, and supports the single small phalanx of the radial or fore finger (*h*.) The middle meta-carpal piece (*f*,) is by much the largest, and supports at its extremity generally three phalanges of the middle finger (*k*, *l*, *m*,) the last of which is very short and slender. The first phalanx (*k*,) of the middle finger has a flat compressed form, like the meta-carpal bone. At the ulnar side of the distal termination of the meta-carpal bone is a small single phalanx of the outer or little finger (*i*,) which is more immediately connected with the exterior slender portion (*g*,)

FIG. 50.

of the meta-carpal bone. When in a state of rest the hand of the bird is folded along the exterior edge of the ulna, and the large primary feathers are thus extended along the sides of the trunk to the tail. These fingers appear to be the analogues of the three middle fingers of the human hand, and there is sometimes a single phalanx covered with a spur on the radial side of these three fingers of the hand of the bird.

The bones of the pelvis, though anchylosed into a single piece, consist of the ordinary three elements on each side, as seen in that of the wild swan, (Fig. 51.) The two iliac bones (*a*,) still extend forwards and backwards from the cotyloid cavity along the sides of the sacrum, as in the saurian reptiles ; and, as they are anchylosed to that bone, the sacro-iliac articulation is here of great extent and security. The iliac bones anchylose behind with the two ischia (*b*,) and the sacro-sciatic notch of mammalia is converted into a foramen (*h*,) but in the ostrich it is a notch open behind, as in most quadrupeds. The ossa ischii are anchylosed at the cotyloid cavity (*f*,) with the pubic bones (*c*,) and the three pelvic bones enter into the composition of that cavity for the head of the femur, as in other classes. The pelvic bones are lengthened backwards, and taper downwards thin and elastic to the anterior part of the pubis, where the two pubic bones (*d*, *d*,) are separate and free at the symphysis, excepting in the ostrich, where they are united by sychondrosis, as in mammalia. The obturator foramen (*i*,) has here a long and narrow form, corresponding with the lengthened form of all the bones of the pelvis. The pubic bones are here free and elastic at their anterior terminations (*d*, *d*,) that they may be susceptible of the necessary dilation, when the large, brittle, and inflexible eggs are passing out through the cloaca, and also to afford the necessary support to the contents of the pelvis. The cotyloid cavities (Fig. 51. *f*,) are generally complete foramina, without an interior osseous septum, and they are placed far forwards upon the pelvis,

FIG. 51.

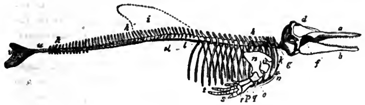
in order to be more under the centre of gravity, to poise alone the entire trunk. The posterior extremities having more of the ordinary use of these members in other animals than the anterior, have their osseous elements constructed more according to the normal character and number of these parts in other vertebrated classes. The head of the femur is small, short, and rounded, with a very short cervix, and projects at a right angle a little lower than the trochanter major, which here forms an extensive arch from before backwards. The femur (Fig. 45. *v*,) in birds is generally very short and strong compared with the succeeding bones of the leg, even in the long-legged grallatores, and the running birds. The air is admitted into this hollow bone, by a large aperture on the fore part of the trochanter major. Between the two prominent sharp condyles of the femur and the upper end of the long tibia is placed the patella, as in quadrupeds. At the upper and outer part of this long and strong tibia (Fig. 45. *w*,) is a small, imperfectly formed fibula, thin, tapering, and anchylosed to the tibia at its lower part, and separate above ; sometimes it is separate throughout. The lower part of the tibia presents a broad, expanded, articular surface for the succeeding long bone of the meta-tarsus, which is single, like the meta-carpal bone of the hand. There is a small tarsal bone in the ostrich, which thus leads to the structure of this part in the lowest ruminantia. The tibia and the meta-tarsal bone are long in most birds, but especially in the wading birds, as cranes and storks. The meta-tarsal bone (Fig. 52. *a*,) has two articular depressions at its upper part, for the two inferior condyles of the tibia, and at its lower end it commonly presents three pulley-like articular prominences (*b*,) for the attachment of the three toes, which are directed forwards. It resembles that of the jerboa among the rodentia. There is generally at the inner and back part of this bone another very small meta-tarsal bone (*c*,) for the attachment of the toe which is directed backwards. The outer toe of birds has five phalanges (1. *d*,)

FIG. 52.

the second has four phalanges (2. *e*,) the third has three (3. *f*,) the inner toe directed backwards has two phalanges (4, *g*,) and the spur seen in the male of many gallinaceous birds is supported by a single osseous phalanx (5.) Where there are only three toes, as in the rhea, and emu, and cassowary, the inner toe has three phalanges, and the outer still five ; and in the ostrich, where there are only two toes, the inner toe has four phalanges, and the outer five, as in other birds ; so that the toes are here deficient on the inner, and not on the outer side of the foot where the number of the phalanges remains uniformly the same. In wood-peckers, parrots, cockatoos, and other zygodactylous birds, the outer and the inner toes are both directed backwards, the better to assist in climbing, and consequently one of these has five phalanges, and the other only two.

XXIII. *Mammalia*.—The bones of mammalia are intermediate in density and compactness of texture, and in the extent of their anchylosis between those of birds and those of reptiles. They have generally thick and solid parietes traversed by numerous sutures, which have disappeared in birds, and in the interior of the long bones are large cavities filled with marrow, which in birds are filled with air, and in reptiles with a cancellated structure. The most imperfect forms of the skeleton are presented by the cetaceous mammalia, where the vertebral column, as in fishes, is the chief organ of progressive motion, and almost alone developed. They have no sacrum, nor pelvic extremities, and their cervical vertebræ are more or less anchylosed together. Their long bones are almost in the condition of those of reptiles, filled with a loose, internal, cancellated structure, containing a thin, serous, or oily marrow, and all their bones have a coarse, fibrous structure compared with those of land mammalia. The head is still extended in a straight line with the vertebral column, the arms are constructed for swimming, and the tail is expanded horizontally, for the vertical movements of the body, required by their aerial respiration, as seen in the skeleton of the porpoise (Fig. 53.) The bodies of the vertebræ terminate in flat surfaces, united to each other by an elastic, fibro-cartilaginous, interposed substance, which admits of the necessary movements by means of its compressibility. The terminal

FIG. 53.



flat portions of the bodies of the vertebra remain long, separate, as detached pieces, in these animals. The cervical vertebræ are sometimes all anchylosed together, and in the herbivorous cetacea, where the neck is longer and more moveable, all the cervical vertebræ are larger, and detached from each other. In the preserved skeletons of the lamantine there are but six cervical vertebræ. The spinous processes extending upwards from the dorsal and coccygeal vertebræ (*h*, *h*, *h*,) are here long and strong, and often support a cartilaginous hunch upon the back, in form of a vertical fin (*i*,) and inferior spinous processes are developed below the coccygeal vertebræ, for the protection of the great blood-vessels. The transverse processes are also long, for the attachment of powerful muscles, and they limit the extent of lateral motion in the column. Many of the last coccygeal vertebræ (*u*,) have only their round bodies developed, and admit of free and extensive motion in every direction. The anterior part of the thorax is the most fixed, to give attachment to the powerful muscles of the neck and of the arms, and the ribs are there attached both to the bodies and to the transverse processes of the vertebræ; but on the posterior part of the thorax, where there is greater freedom of motion, the ribs are attached only to the ends of the long transverse processes. There are no bones extending into the fin-like cartilaginous hunch (*i*,) upon the back, nor into the lateral cartilaginous expansions of the tail (*v*,) as we find in these parts in fishes. The sternum is very short, and confined to the anterior ribs, and the sternal ribs are generally ossified, as in many other quadrupeds, and in birds, and in many reptiles. Although there are no legs, we always

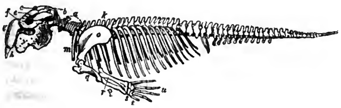
find here two lengthened slender pelvic bones, unconnected with the rest of the skeleton, and having the rib-like form of the iliac bones of fishes and amphibia.

The head is most lengthened, straight, and fish-like in the piscivorous cetacea, as the porpoise (Fig. 53,) where the face is chiefly composed of the long maxillary and intermaxillary bones, (*a*,) and the vomer, which is extended between them. The small nasal bones are placed far backwards upon the forehead, behind the nasal apertures, and behind them is the narrow band of the frontal bone, which is in contact with the occipital, from the parietals being confined to the temporal region of the head. From the great extent and the vertical position of the occipital bone, and the extension of the maxillary bones upon the forehead, the cranium is here generally small, compared with the face, and is much extended transversely; great extent of surface for muscular attachment is thus given to the back part of the head, and great development to the jaws in front, for prehension. The teeth, like those of fishes and reptiles, are adapted for prehension, and not for mastication; they are similar in form, conical, bent, and placed alternately in the opposite jaws. In the cachalots, they are present only in the lower jaws, which are very narrow, and in contact with each other throughout the greater part of their course, and thus are opposed only to the middle part of the roof of the mouth. In the fœtus of the balæna there are teeth in the lower jaws, which soon entirely disappear, and the alveolar margin of the upper jaws are occupied with vertical, long, thin, horny laminæ, which are fimbriated on their inner edges, and by straining the water, they collect the small floating animals on which the whales feed. The malar bone forms the lower boundary of their very small orbit (*f*,) and is here a remarkably thin, slender, and curved bone, compared with the massive malar bone of the herbivorous species, which require a more powerful masseter for mastication. The petrous and tympanic portions of the temporal bone, though anchylosed together, are connected only by cartilage to the other bones of the skull, the ethmoid bone presents no cribriform plate, and the infraorbitary foramen is divided into a series of small apertures extending forwards along the upper jaw-bones. The right side of the head is generally

more developed than the other, and the nostrils are inclined thus to the left side. The arms of these cetacea are moved in a piece, as fins, and the articulations of the several bones, especially of the hand, are very imperfectly formed. There is no clavicle, but the great expansion of the scapula (Fig. 53. *n*,) presents a large surface for the powerful muscles of the humerus, by which the arm is chiefly moved, the succeeding bones being scarcely moveable on each other in the living state. The humerus (*o*,) has a large round head, but is compressed at its lower end, like that of a turtle, and the same compressed form is seen in the radius (*p*,) and the ulna (*q*,) and in the detached round bones of the carpus (*r*,) the meta-carpus, and the phalanges of the five fingers (*s*, *t*.)

In the herbivorous cetacea, as in the dugong (Fig. 54,) we find a much nearer approach, in many parts of the skeleton,

FIG. 54.

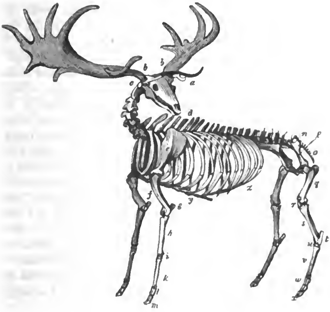


to the ordinary condition of these parts in the land quadrupeds, than in the piscivorous tribes, especially in the forms of the jaws and teeth, in the cervical vertebræ, and in the whole bones of the arms. The cervical vertebræ (*a*,) are here detached and moveable on each other, and the neck is thus longer and more flexible. The occipital bone (*b*,) rises to a much less extent upon the cranium and its elements, like those of most of the other bones, remain long disunited. The cranical cavity is smaller considerably than in the former group. All the sutures of the cranium remain very loose, and the petrous and tympanic portions of the temporal bone are permanently detached from the squamous, as in the other cetacea. The frontals are divided by a continuation of the sagittal suture ; the malar or jugal

bones (*f*,) are here of great size and strength, the jaws are of great depth, for the long molares, with flat crowns adapted to their vegetable food, and the intermaxillary bones (*g*,) are of great size, for the long and large incisors (*h*,) which they contain. The lachrymal bone forms a small portion of the margin of the orbit, and is interposed between the anterior end of the jugal bone and the malar process of the frontal. The muzzle is straight in the predaceous tribes (Fig. 53. *a*,*b*,) and thus directed to the prey, which floats or swims in the water ; but in the herbivorous cetacea it is bent down to the fuci, which are attached to the bottom of the sea. As the neck is here more lengthened and moveable, the trunk is more fixed in its condition by the development of the sternum and of more numerous and larger ribs, the pelvic arch is more complete, and the inferior spinous processes of the coccygeal vertebræ are larger and stronger. The whole bones of the arms are constructed more according to their normal forms in the land mammalia, and these animals are able to clamber upon rocks on the sea shore, like seals and walruses, and to manipulate their young while sûckling at their pectoral mammæ. The scapula (*o*,) is more narrow and lengthened, the humerus (*q*,) is longer and more cylindrical than in the blowing cetacea, and the radius (*p*,) and ulna (*r*,) have a more lengthened and rounded form, and admit of more extensive motion at both extremities. The forms and articulations are more complete, and admit of freer motion in all the bones of the carpus (*s*,) and meta-carpus, and in the phalanges of the fingers (*u*) ; so that the hands possess much more prehensile power in the herbivorous than in the piscivorous cetacea.

The skeletons of ruminating quadrupeds still present many marks of an inferior grade of development, when compared with carnivorous and higher orders of mammalia, especially in the small size of the cranial cavity, compared with the face, in the deficiency of teeth in the jaws, in the want of clavicles, and in the imperfect condition of the arms and legs, and of the hands and feet, as seen in the skeleton of the fossil elk (Fig. 55.) Their frontal bone, which generally develops horns from its tuberosities, is divided by a longitudinal suture, and the parietals are anchylosed together, to consolidate the skull behind. The tuberosities of

FIG. 55.



the frontal bones in the males of most genera of this order, extend upwards into permanent processes, of a loose cancellated structure, which are covered with permanent, horny, and extravascular sheaths, as in antelopes, sheep, goats and oxen. In the deers the antlers are deciduous, organized osseous processes, continued from the same tuberosities of the frontal bones, with thick, dense, and very compact parieties, and a softer internal core passing through all the branches. These deciduous horns, which are diverticula of the blood at stated seasons, and intimately connected in their development with the condition of the genital system, are annually cast and renewed, each successive pair being larger and more complex in form than the preceding. There are permanent rudimentary osseous horns in the giraffe, together with a median frontal eminence, like that on the frontal bone of the two-horned rhinoceros ; but there are no horns in the camels, dromedaries, lamas, pacas, and

musk-deers, where there are canine teeth, and they are wanting in the females of most ruminantia. The orbits are thrown to the sides of the head by the great development of the frontal bones, which are chiefly occupied with air; from the large sinuses, they communicate with the temporal fosse, but have a complete osseous margin by the extension downwards of the malar process of the frontal to the jugal bone. The lachrymal bone extends downwards over the face, to assist in lengthening the head, the alveolar portions of the jaws are deep, for the long malar teeth, and the broad nasal bones cover a large and long nasal cavity. The turbinated bones are of great size, the malar bone is prolonged over the face, the zygomatic arch is very small, and has the coracoid process of the lower jaw extended to a great height through it, which limits the lateral motion of the lower jaw during mastication. The long slender intermaxillary bones are generally destitute of teeth, the malar teeth with oblique crowns have the layers of enamel directed longitudinally, the motion of the lower jaw being from side to side. The lower jaw being much narrower than the upper, the lateral motion is required to bring the teeth into apposition for mastication, and the glenoid and condyloid surfaces are therefore flat, to admit of this extensive motion. The cervical vertebræ (Fig. 55. *c*,) are of a lengthened form, with short processes, to give length and mobility to the neck, and the spinous processes of the dorsal vertebræ (*d*,) are long, for the attachment and support of the long neck and often weighty head. The ribs extend over a great part of the trunk (*z*,) and the transverse processes of the lumbar vertebræ are of great length, to assist in the support of the heavy abdominal viscera. The pelvis (*p*,) is lengthened backwards, the sacro-iliac articulation (*n*,) is more or less oblique, to give greater elasticity to the movements of the legs, and the coccygeal vertebræ (*o*,) are numerous and highly moveable, the tail being generally employed as a hand, to brush away insects from the surface of the body. The anterior part of the thorax, destitute of clavicles, is so compressed that several of the first pairs of ribs are almost straight, by which the arms are approximated and brought more nearly under the centre of gravity of the heavy trunk, from which they would have been thrown out and endangered by the

interposition of clavicles. The elements of the sternum (*y*,) placed in a line, are extended longitudinally, like the ribbed part of the trunk, and are generally narrow and compressed laterally. The long narrow scapulæ (*e*,) have scarcely the rudiments of the acromion and coracoid processes developed. The humerus (*f*,) and the femur (*q*,) are generally short and strong bones, much inclined from the vertical position, especially in the lighter and nimbler forms of this order. The secure articulations of the long radius (*h*,) and tibia (*s*,) admit of free flexion and extension, but are fixed in a state of pronation. The imperfect ulna is anchylosed below to the back part of the radius, and consists chiefly of an elongated olecranon (*g*,) to secure the elbow joint and afford a strong attachment to the extensor muscles of the arm. At the lower end of the radius are found the four usual small carpal bones of the first row separate, and the four of the second row are here generally anchylosed into two pieces (*i*,) which form the articulation with the long single meta-carpal bone (*k*.) This broad meta-carpal, like the compressed meta-tarsal bone, consisted in the fœtus of two separate bones, and it retains, in the adult state, longitudinal median grooves before and behind, which mark the line of original separation. There are often likewise the slender rudiments of two other meta-carpal and two meta-tarsal bones seen, one on each side of these long anchylosed bones of the meta-carpus (*k*,) and metatarsus (*v*,) and the rudiments of two corresponding toes are found at the sides of all the feet. There are two long pulley-like articular condyles at the lower end of the meta-carpal bone, and there are three phalanges on each of the two toes prolonged to the ground. The trochanter major is large, and elevated on the strong and short femur (*q*); the long and strong tibia (*s*,) forms the whole articulation with the femur and with the astragulus (*u*,) and fibula forms only a small splint. The calcaneum (*t*,) extends upwards in the elevated heel, like the olcranon (*g*,) at the elbow. Besides the astragulus and calcaneum, there are generally two cuneiform bones, and a compound cubo-scaphoid bone in the tarsus of ruminantia; but there is one more bone in the camel, as in the tarsus of the solidungulous pachyderma. The long, anchylosed, compound meta-tarsal bone (*v*,) is more compressed and narrow than the corresponding broad and

flattened meta-carpal (*k*,) of the hand, and has attached to its inferior pulley-like articular processes two toes (*l*, *m*,) prolonged to the ground, which like the fingers of the hands, have three phalanges in each. Great elasticity is given to the extremities in the ruminating quadrupeds by the alternately inclined direction of most of the bones, and great security is given to the articulations by the pulley-like form of nearly all the joints.

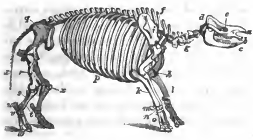
The skeletons of the pachyderma, like those of ruminating quadrupeds, have no clavicles, and have the jaws and teeth adapted for vegetable food ; the articulations are constructed generally for limited, slow, and secure movements, and the bones are more strong and massive in their proportions. The nearest approach to the ruminating form of the skeleton is that of the solidungulous quadrupeds, where we observe, as in the camels, three kinds of teeth in the jaws. The jaws and face are there lengthened to reach the turf, and the upper and lower maxillary bones are of great depth, to lodge the long prismatic, quadrangular molar teeth. The cranial cavity is small, as in all the pachyderma, and the orbits are surrounded with an osseous ring, as in the ruminantia. The transverse ridge of the occipital bone is much elevated, for the attachment of the strong muscles and ligaments of the neck. By the great development of the interposed bones, the orbits are thrown to the extreme lateral points of the head, and directed to the sides. The ethmoid bone presents internally two large and deep fossæ for the olfactory tubercles, and the turbinated bones present a very extensive surface, for the distribution of the first pair of nerves. In their long neck, their long spinous processes of the dorsal vertebræ, the compressed form of the thorax, the lengthened form of the bones of the scapular and pelvic arches and of their extremities, they more approach to the ruminantia than to the ordinary short and massive forms of the pachyderma, and the anchylosis which extends in the ruminating quadrupeds only through the inferior row of the carpal and tarsal, and through the meta-carpal and metatarsal bones, is here continued downwards through the phalanges of the two middle fingers and toes to the extremity of the hands and feet.

In most of the ordinary pachyderma, as the pecari, the babyrussa, the tapir, the hippopotamus, and the rhinoceros the

back part of the skull presents an elevated transverse ridge, and a broad surface of attachment for the muscles and ligaments of their heavy head and strong neck, the head being sometimes employed in digging, as in the hog tribe, or to support a strong instrument of defence, as in the rhinoceros, or being proportionally large and weighty, as in the hippopotamus. The air is admitted from the frontal sinuses over a large portion of the diploe in the babyrussæ and other animals of the hog tribe, to extend the external surface without adding to the weight of the head, as we see to a much greater extent in the huge head of the elephant. All the processes of the cervical vertebræ are here more strongly developed than in the long flexible neck of the ruminantia, and the spinous processes of the dorsal vertebræ are lengthened and strong, and generally terminated by round tubercles. The scapula is generally broader at its vertebral margin, and the strong pelvic arch is more vertical in its direction. The extremities are generally shorter and more massive, and the separate bones more completely formed than in the former groups of quadrupeds, the ulna and the fibula being developed throughout, and four toes, at least, generally reaching the ground on all the extremities. As the kind of vegetable food varies much more here than in the ruminating quadrupeds, there is a greater diversity in the forms of the teeth, and of the jaws, and of many other parts of the skeleton.

The general forms and proportions of the bones most common in the ordinary pachyderma are seen in the massive skeleton of the rhinoceros (Fig. 56,) where the head and neck are more lengthened than in the proboscidian tribe, and the trunk is almost en-

FIG. 56.

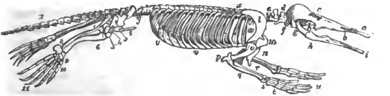


tirely encompassed by large and broad ribs. The fore part of the head presents an arched appearance from the elevation of the anchylosed nasal bones (*a*,) for the support of the horn, and the intermaxillaries (*b*,) are very slender and short, and contain each a single incisor tooth. The orbits (*e*,) are quite continuous with the temporal fosse, as in the tapir, but in the hippopotamus they are surrounded with a bony margin, as in the solidungula. The inferior molar teeth are here remarkably narrow, when compared with the broad cubical crowns of those of the upper jaws, and the two long conical inferior incisors (*c*,) project forwards, like those of a hippopotamus. The great elevation of the occipital bone (*d*,) the great size of all the processes of the cervical vertebræ (*g*,) and the magnitude of the spinous processes of the dorsal vertebræ (*f*,) indicate the force with which the head is moved, and the powerful offensive instruments which it supports. In the two-horned species the anterior part of the frontal bone is raised, like the nasal bones, into an arch for the support of the posterior horn. The infra-orbitary foramen is of great size, for the nerves of the large expanded upper lip, like that of the elephant, for the nerves of the proboscis. The spinous processes continue large and strong on the lumbar, and even the sacral vertebræ, and the sacro-iliac articulation (*q*,) is nearly vertical to that of the femur with the cotyloid cavity, as in many of the other ponderous skeletons of pachyderma. The spine of the scapula (*i*,) arches backwards over the infra-spinati muscles, as in the elephant. The ulna and the fibula are developed and distinct throughout their whole extent, and the olecranon of the arm, like the patella of the leg, is of great size, as are the muscular processes of all the bones of the extremities. The iliac bones (*q*,) are expanded transversely, the tuberosities of the ischia extend outwards, and the cotyloid cavities are directed downwards. Three toes are continued to the ground before and behind, consisting each of three phalanges, the two first of these phalanges have a broad cubical form, and the last is remarkable for its rough irregular form, and its extension transversely. The terminal phalanx of the middle toe on all the feet is elongated transversely on both sides, but in the other toes it is elongated only on one side, that most remote from the middle toe; so that ample support is

afforded to the broad hoofs, and a broad base for the ponderous carcase of this powerful quadruped. The carcase being still more ponderous in the elephants, the scapular and pelvic arches, and the whole extremities, are more vertical in their direction, and the scapular and iliac bones are of great breadth. The heavy molar teeth, and the large tusks, and the large proboscis give so much weight to the head, that the neck in these proboscidian animals is very short, and the external surface of the cranium is greatly extended for muscular and ligamentous attachments, without adding to the weight of the head, by the vertical cells of the diploe being filled with air admitted through the Eustachian tubes. From the strong attrition to which the molar teeth of the elephants are subjected, they are composed of numerous thick transverse plates of enamel enclosing the osseous portions and united together by an enveloping crusta petrosa, and they are successively worn down to their base, and replaced by new teeth from behind, for eight or nine times during the life of the animals, while the long tusks are renewed but once. The base of the lower jaw projects more than the human.

In the monotrematous animals the skull is thin, smooth, and diaphanous, and with a lengthened toothless muzzle, as in birds, as we see in the skeleton of the ornithorhyncus (Fig. 57,) where there are only two horny thin crowns of molar teeth (*h*,) at the back part, and on each side of the two jaws.

FIG. 57.



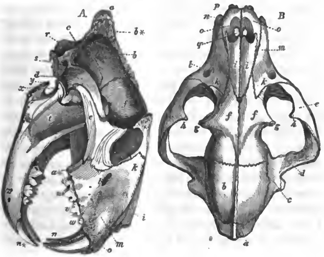
Their intermaxillary bones converge at their free anterior extremities; there is a median longitudinal osseous crest in the ornithorhynchus, extending along the interior of the occipital and parietal bones, and the occipital foramen (*d*,) is prolonged upwards, narrow in a vertical direction. The scapula (*l*,) especially in the ornithorhyncus, is lengthened

and curved backwards, like that of a bird; and, as also in that oviparous class, the large coracoid bones reach and unite with the sternum, the clavicles (*m*,) meet and are anchylosed together in front, and the sternal appendices are ossified. The ribs encompass a large proportion of the trunk, and long marsupial bones (l,) are extended forwards from the margin of the pubic bones. The long arms and legs, and the extended feet of the ornithorhyncus suit it for its aquatic life, while the stronger extremities and short feet of the echidna are suited for digging in the ground. In many of the edentata the upper and lower jaws are long, narrow, curved, and toothless, as in birds, and the trunk, as in the armadillos, is surrounded with very broad ribs. The pubic bones also are often lengthened backwards, and meet at a very narrow symphesis, and there is generally a sacro-sciatic foramen, as we find in birds, in place of the ordinary sacro-sciatic notch of quadrupeds. In the sloths there are false ribs anterior to the true ribs, as well as behind them, as we observe in most of the oviparous vertebrata, and the zygomatic arch is open in some of the ant-eaters, as the *myrmecophaga jubata*. From the longitudinal movement of the lower jaw in the rodentia, its condyles are extended longitudinally, and the layers of enamel are disposed transversely in the molar teeth. Their two chisel-shaped incisors above and below are kept sharp by means of the thin layer of very dense enamel which coats their anterior surface, and the broad crowns of their molares are kept rough by the unequal densities of the layers of enamel and of osseous substance which compose them. As the cerebral hemispheres are destitute of convolutions, the surfaces of the skull are thin, smooth, and often diaphanous, as in birds, and the squamous portion of the temporal bone generally remains long separate from the other elements of that bone. The mastoid bone generally forms a large bulla communicating with the tympanum, as in the carnivorous quadrupeds, and the orbit is here also continuous with the temporal fossa. The intermaxillary and the nasal bones are of great size, the zygomatic arch has its convexity directed downwards, and the palatine holes are of great size, as in birds. The clavicle is sometimes complete and strong, and in many it is developed only in its central part; the sacrum and the iliac bones are long, and the pelvis is extended backwards,

as in many edentulous quadrupeds and birds. Although the radius and the ulna are free on the arms, the fibula is very imperfect, and is anchylosed to the tibia on the posterior extremities. Notwithstanding the differences observed in the skeletons of the different kinds of marsupial quadrupeds, they agree in the possession of two triangular, lengthened, marsupial bones articulated moveably to the anterior margin of the pubes, and extending forwards behind the pouch and the mammary glands, and in contact with the recti muscles of the abdomen.

The skeletons of carnivorous quadrupeds have generally the bones of a more compact and dense texture, combining lightness with strength in their forms, and secure, yet freely moveable in their articulations, which corresponds with their great muscular development, with the extent of their respiratory system, with the increased energy of all their functions, and with their living wants and instincts. From their great cerebral and intellectual development, their cranial cavity is comparatively large, and to give strength to their jaws their face is generally short and broad, as seen in these skulls of the Bengal tiger, *felis tigris* (Fig. 58. A. B.) The transverse occipital ridge (*a*,) is remarkably high and prominent, for the strong muscles of the neck, as also the longitudinal ridge (*b*, *b*,) extending forwards along the occipital and parietal bones, which

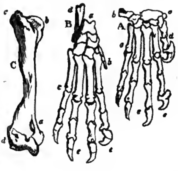
FIG. 58.



alone separates the the two large temporal muscles from each other. The sides of the cranium often assume a compressed form, especially where the temporal muscles are of great force as in the hyæna and in old carnivora, where many of the cranial sutures also disappear. The mastoid process (A. r,) forms a large cavity or bulla communicating with the tympanum, and enlarging the organ of hearing in these as in other nocturnal animals. The zygomatic arch (*e, e,*) is of great magnitude and strength, and is convex above. The temporal fossæ are continuous with the orbits from the deficiency of the frontal, (B. *g,*) and the malar bone (B. *h,*) behind the orbits, and the zygomatic process (B. *c, d,*) extends laterally at a right angle from the squamous portion (A. *c,*) of the temporal, in order to form a long transverse glenoid cavity for the transverse articular condyle (A. *x,*) of the lower jaw. The parietal bones (*b, b,*) early anchylose in the animals of this order, so as to resist the tearing action of the temporal muscles, which have a great surface for insertion on the large coronoid process (A. *t,*) which forms the entire ramus of the lower jaw. There is a strong ossified tentorium extending inwards between the brain and cerebellum, to protect these delicate organs from the effects of their leaping and bounding movements. The infra-orbitary foramen (*l, l,*) is large for the nerves of the upper part of the face, and the upper part of the nasal cavity is enlarged for the ethmoid and turbinated bones, by the great breadth of the nasal process (*k, k,*) of the superior maxillary bone and of the nasal bones. (*i, i.*) The intermaxillaries (*o, o,*) contain each three teeth, the outer of which are the largest, and the canine teeth (*n, n,**) above and below are large, conical, curved, and inserted in very deep alveoli. (*m, m.*) The large transverse condyle (A. *x,*) of the lower jaw is little raised above the base, and is secured in a very deep glenoid cavity of the temporal bone that the jaws and teeth may meet with great precision, especially the molar teeth which have sharp cutting crowns (A. *u, v, w,*) directed longitudinally, and entirely covered with a very dense and thick layer of enamel. The anterior small detached molar teeth (*w,*) behind the canine (*n,*) are the *false molares;* the larger prominent cutting molar tooth, with a tubercle at the interior of its base, is the *carnivorous tooth;* (A. *u,*); and the flat broad-crowned tuberculated teeth, which are more or less developed behind these are the *tuberculated*

molares, (A. *a.**) of which there is only a very small one in the feline carnivora. The lachrymal bone is here almost confined to the orbit. By the zygomatic arch being carried forwards beneath the orbit and the condyle of the lower jaw being extended backward, the masseter muscles act with great force and advantage on the lower jaw, their place of insertion being, like that also of the temporal, considerably anterior to the point of resistance and of rotation. The transverse processes of the atlas and the spinous process of the axis are of great length, and the processes generally of the cervical vertebræ for the strong muscles of the neck, by which they have to tear their food to pieces, or to carry their victims to a place of retreat. There is great strength with flexibility in all parts of the vertebral column, and hence their slender ribs encompass a smaller portion of the trunk than in the ponderous bodies of the pachyderma, but their thoracic cavity is wide and capaceous. The lumbar region is extensive, and the transverse processes of the vertebræ are there directed forwards. The sacro-iliac articulation is very oblique, giving greater elasticity to the attachment of the legs to the trunk, and the coccygeal vertebræ are generally very numerous and moveable. The scapula is broad and strong, the clavicles imperfect or wanting, and the muscular processes of the bones of the arm and fore-arm are strongly marked. Above the inner condyle of the humerus (fig. 59, C. *a*,) is a large oblique foramen, through which the ulnar artery passes forwards, protected from external pressure, as we see also in some of the climbing quadrumana. In the soft and flexible hand of the carnivora, as in that of the tiger (fig. 59, A.), the carpal bones are generally reduced to seven by the anchylosis of the scaphoid and lunar bones (*a*), and the succeeding bones of the metacarpus (*c*) and the phalanges of the fingers (*d*, *e*,) present strong and secure articulations, the last phalanx on the hands (*e*, *e*,) as on the feet (B. *e*, *e*,) being directed upwards to preserve the sharp claws

FIG. 59.



from abrasion. The inner toe of the anterior and posterior extremities (A. *d*, B. *b*,) so imperfectly developed in most of the digitigrade carnivora is generally longer in the plantigrade and the aquatic species.

In the true insectivorous quadrupeds without wings, as the hedge-hogs shrews and moles, the jaws are more lengthened, the canine teeth are often small, the molar teeth have broad crowns with an outer and inner row of sharp-pointed tubercles to seize and bruise the insect food, the scapular arch is strengthened by clavicles, the radius and ulna are separate and moveable on each other, the rudimentary fibula is anchylosed to the tibia, all the feet are plantigrade and pentadactylous and the toes and claws are strong for scraping and digging. The orbit is continuous with the temporal fossa, the zygomatic arch is very slender and straight, the infra-orbitary foramen large, and the articulation of the lower jaw flat. There is great mobility in the articulations of the hedge-hogs, as in other spiny and scaly quadrupeds, to allow of their coiling their body into the form of a ball for protection. The anterior portion of the skeleton is more developed than the posterior in the moles, to enable them more easily to burrow, and in the cheiroptera to favour their flight through the air. The cranial bones, the occipital, the parietal, and the frontal, are remarkably extended forwards in the mole, compared with the extent of the anterior bones of the face. The coronoid process of the lower jaw rises high through the zygomatic arch, and the angle of the jaw is prolonged backwards and a little inwards over the mastoid portion of the temporal bone. The fore part of the septum of the nose is ossified in this animal as in the hogs, to support the nose in digging. The spinous process of the axis is large and extended backwards, but the succeeding cervical vertebræ are like narrow distant rings, almost destitute of spinous and transverse processes, to allow the freest motion in this part with safety to the enclosed spinal chord. The sternum is extended forwards to a great distance before the first pair of ribs, and is carinated like that of a bird, to afford an extensive surface of attachment to the large pectoral muscles; and for the same reason, as well as to lodge large respiratory organs, the ribs encompass a widely expanded thoracic cavity. The clavicles are very short and strong, the scapulæ long and narrow, the

humerus short and widely expanded at both ends, the olecranon of great magnitude and extent, the bones of the hand short, fixed, and strong for rapidly excavating the ground, and one of the carpal bones is lengthened and curved forwards to increase the inner surface of this digging instrument. The pelvis and the posterior extremities are very small, the pelvic bones are anchylosed to the sacrum, the pubics are separate in front, and the fibula is reduced to a small process of the tibia as in most other digging and burrowing quadrupeds.

The skeletons of the cheiroptera are constructed for flight and present, as in the moles, the anterior portion much more developed than the posterior. The jaws are lengthened for the reception of numerous broad-crowned sharp-tuberculated insectivorous molar teeth. The canine teeth are generally long and pointed, the intermaxillary bones small and imperfectly ossified, the palatine bones separate, the zygomatic arch is very feeble, and the orbits, for their very small eyes, are continuous with the temporal fossæ, as in carnivora. The bones of bats are generally light and compact in their texture and some of their ordinary sutures, as the sagittal, early disappear in the cranium. The orbit is surrounded with a complete osseous margin in the *pteropus*. In the *rhinolophus* the intermaxillaries are small, soft, and cartilaginous, and contain each but one incisor tooth; and in the *nycteris* these bones are united by a moveable articulation to the upper jaw-bones, like the moveable upper bill of parrots and cockatoos. The cervical and lumbar regions of the skeleton admit of free motion, and the long iliac bones are often anchylosed to the sacrum as in the feathered tribes. The coccygeal vertebræ are often prolonged to support an inter femoral membrane, as in the pteropus and rhinolophus. The long pubic bones scarcely meet at the symphesis, and the cotyloid cavities are directed obliquely backwards which assists in the retroversion of the feet. The scapulæ have a broad expanded form, the clavicles are long and strong, the coracoid process is lengthened and curved downwards and inwards, and the fore part of the sternum is often deeply carinated like that of a bird. The long cylindrical humerus is succeeded solely by the radius in the fore-arm, the ulna being reduced to its olecranon, which often forms a separate

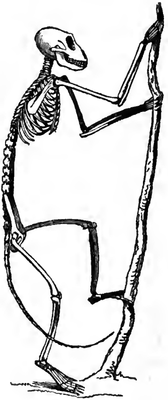
moveable patella at the elbow, like that of the knee-joint. The carpal bones occupy a very small space in the hand, and the long fingers are here fixed in a state of extension, as they are in the hand of the bird, the thumb alone admitting of free flexion and extension. The hand of the bats rotates on the carpal end of the radius by a motion of abduction and adduction, as the wing of the bird, so that, when folded, the little finger lies along the outside of the radius. The thumb is not enclosed in the interdigital membrane, but is extended forwards free as a prehensile organ for progressive motion, or for suspending its body. The long slender meta-carpal bones and phalanges of the four succeeding fingers support the interdigital membrane, and there are often claws on the fore and on the middle finger. The small legs are twisted outwards from their commencement in the oblique cotyloid cavities of the open pelvis. The femur is of a cylindrical form, slender, and with a large articular head, and a large trochanter minor directed forwards, the trochanter major being here turned backwards. The fibula is broad at its tarsal extremity, but is almost lost before it reaches the upper end of the long slender tibia. From the retroverted direction of the cotyloid cavities and of the whole legs the tibia is placed externally, and the fibula internally. The short bent calcaneum directed inwards has often extending from its tuberosity, along the margin of the interfemoral membrane, a slender elastic bone, which supports that membrane. The slender parallel toes directed backwards terminate in long, curved, sharp prehensile claws, by which they most frequently suspend their body in an inverted position, the best suited for their launching instantaneously into the air with outspread wings, when called by hunger or alarm.

In the lowest of the quadrumanous animals, as the lemurs of Madagascar, the jaws are still lengthened for numerous insectivorous molar teeth, and the skeleton generally is adapted for the horizontal position of the trunk. The occipital foramen is placed near the posterior margin of the skull, the mastoid cells are as large as in carnivorous quadrupeds, and although the orbit is here surrounded with an osseous margin, it is still continuous behind with the temporal fossa. The cranial cavity, however, is here capacious,

and the ordinary sutures of the human cranium continue permanent, as in the higher forms of quadrumana. The sagittal suture often traverses the frontal bone, and the anterior frontals are sometimes seen separate. The temporal fossa is small, the zygomatic arch feeble, the condyles of the lower jaw and their glenoid cavities flat, the lachrymal bones extend downwards from the orbits, and are perforated on their facial surface, and the nasal bones, unlike those of higher quadrumana, are broad, long, straight longitudinally, and form an expanded arch in their transverse direction, as in carnivora and other inferior tribes. The ramus of the lower jaw is still very short, its condyles are nearly as low as the alveoli of the teeth, and the coronoid processes rise high through the zygomatic arches. The inferior incisor teeth, four in number, as in the simiæ and in man, project straight from the lower jaw, as those of a kangaroo, and this direction is seen also in the *stenops*, the *galago*, and the *lichanotus*. The face and entire head become shorter as we ascend through these genera to the true simiæ of the old and new continents. In the simiæ the lamdoidal, the sagittal, the squamous, and the coronal sutures advance forwards on the cranium more and more as the cerebral centres and the cranial cavity enlarge, and the face becomes proportionally small. As the muzzle shortens, the facial angle encreases by the elevation and expansion of the frontal bone, and by this shortening of the jaws less space is afforded for numerous molar teeth. The orbits approximate, assume an anterior and parallel direction, separated only by a narrow ethmoid, and their communication with the temporal fossæ is cut off by an osseous partition formed by the extension of the frontal and malar bones. The temporal fossa becomes reduced in size, the zygomatic arch short and straight, the condyloid articulation of the lower jaw flat and free, the lachrymal bone confined to the orbit, and the nasal bones flat, narrow, short, and often anchylosed together. The intermaxillaries continue permanently separate up to the orangs, and the incisors, four above and below, as in man, continue more inclined forwards than in the human jaws. The canine teeth, as instruments of prehension and of defence, continue large and projecting, and the sharp tubercles of the molar teeth of the insectivorous and nocturnal

makis, become more short and rounded in the higher quadrumana, correspond with the softer quality of their succulent and juicy food. The ramus of the lower jaw ascends higher and more abruptly, and the coronoid process is reduced in length and strength. The occipital foramen advances forwards on the base of the skull by the expansion of the posterior region, and the occipital bone becomes confined to the basilar aspect of the cranium. The supra-orbitary foramen is generally absent, or a mere notch, and the infra-orbitary hole is commonly divided into several small apertures. In the orangs the internmaxillaries anchylose to the upper jaw-bones, and to each other in the adult, as in the human jaws. The general forms of the bones and articulations of the rest of the skeleton are adapted for the semi-erect or climbing position of the trunk, as seen in the skeleton of the mona monkey, *cercopithecus mona*, (Fig. 60.) The cervical, and lumbar, and coccygeal regions of the column generally admit of free and extensive motion. The cervical vertebræ have their spinous processes simple and pointed, the dorsal vertebræ nearly of the same number as in man, and the lumbar vertebræ encreased in number at the expense of the sacrum. The transverse processes are more directed forwards towards the head than the human in these free and moveable lumbar vertebræ. In the prehensile tails

FIG. 60.

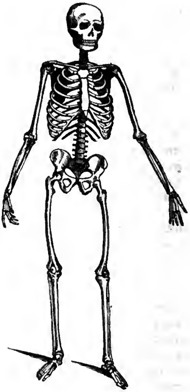


of most of the American quadrumana the coccygeal vertebræ are encreased in number and mobility, and in the strength of their articulations; they are generally more lengthened and cylindrical in the long-tailed quadrumana of the old continent. The scapulæ are still lengthened and narrow, but with an elevated spine, the clavicles are strong, and curved like the human, the coracoid and acromion processes are of considerable size, and the glenoid cavity comparatively deep. The humerus is more curved than the human, and the radius and ulna are more lengthened and slender, and admit of very free pronation and supination. There are often nine bones in the carpus by the division of one in the second row, to give greater mobility and prehensile power to the whole hand, and for the same object all the bones of the meta-carpus, and the phalanges of the fingers, which have the same number of bones as in the human hand, are much lengthened. The thumb is shorter and less opposeable to the other fingers than in man. The posterior members have the same long, slender, and prehensile character as the anterior. The sacrum generally consists of three anchylosed vertebræ, the iliac bones are long and narrow, and directed longitudinally, and the tuberosity of the ischium expands outwards, covered with the callosities on which these animals generally rest. The femur is much curved, its neck short, and the trochanter major much elevated. The long, slender, and separate tibia and fibula admit of free motion in the foot, as a prehensile organ, and which is increased by the shortnessof the tuberosity of the calcaneum.The astragalus is twisted obliquely outwards, and this inclination, increased by the form of the calcaneum, is communicated through the scaphoid and cuboid, and the three cuneiform bones to the meta-tarsus and the whole foot, which is thus made to rest obliquely on its outer margin, and the inner toes are raised from the ground, and left free for prehension. The inner toe of the foot is here attached in a very oblique manner to the internal cuneiform bone, which is placed much below the others, and it is thus opposed slightly to the other more lengthened toes of the foot, and that organ is converted into a prehensile hand. In the highest of the quadrumana, the chimpanze of Africa, the nasal bones are more raised from the face, the incisors more vertical, and

the facial angle greater than in the inferior forms, the scapulæ and the iliac bones are more expanded, the calcaneum extends more backwards, and the forms and proportions of all the bones of the skeleton approach most closely to the human.

The forms of the bones and of the articulations of the human skeleton are adapted to support the trunk in a vertical position upon the feet, by which the organs of the senses are directed forwards, and the arms are left free, for various employments. By the great development of his cerebral organs, and the superior elements of his cranial vertebræ (Fig. 61,) the skull is large, and its cavity capacious. The organs of the senses being confined to a narrow space the face is small, and it is nearly straight from the frontal bone to the chin, from the slight projection of the muzzle, excepting in the negro, where the projection of the jaws and teeth, and the receding of the frontal bone, reduce the facial angle more near to that of the orangs. The occipital foramen, and the two occipital condyles are advanced further forwards on the base of the skull than in any of the quadrumana; so that the head is more nearly poised by the centre of its base on the atlas, and on the vertical column of the trunk. The forehead, and nasal bones, and the chin project more than in the nearest quadrumana, the

FIG. 61.



incisors are more nearly perpendicular, the canini shorter, and the tubercles of the molares more rounded, corresponding with the softer condition of his food. The squamous portion of the temporal bone, the great ala of the sphenoid, and the superior portion of the occipital, are here more largely expanded; the temporal fossa, the zygoma, and the coronoid process of the lower jaw are small. The ramus of the lower jaw is larger, and forms a more acute angle with the base, the condyle is more elevated and convex, and the glenoid cavity for its reception is deeper than in the quadrumana. The nasal process of the superior maxillary and the lachrymal bone pass more into the orbit, and the orbits are more parallel in their direction, which gives greater precision to all visual impressions. The vertebral column in the direction of the median plane has a greater sigmoid curvature; the cervical vertebræ have their spinous processes more broad, short, and bifurcated; the transverse processes of the lumbar vertebræ extend more at a right angle from the bodies; the sacrum is longer, broader, and more arched, and the coccyx is comparatively small. The ribs are more convex, the sternum shorter and broader, the clavicles are more curved and strong, and the scapula is shorter and more expanded at its vertebral margin. The glenoid cavity of the scapula is more lateral in its direction, the humerus, with a large articular rounded head, is more straight; the olecranon of the ulna is comparatively short, and the bones of the thumb are more lengthened and more opposeable to the other fingers. The pelvis is shorter and broader than in the inclined bodies of the quadrumana; the iliac bones are more expanded and convex, more extended over the acetabulum, and with a longer crest; the tuberosity of the ischium is less prominent, and the symphesis pubis is shorter. From the greater breadth of the pelvis, the femora are more distant from each other, their head has a less extensive articular surface, and is marked by the ligamentum teres which is absent in the orangs; the cervix femoris is longer, and directed more obliquely downwards, and the trochanter major is less elevated. The bones of the legs, stronger and more distant from each other, afford a broad and secure base of support for the erect and weighty trunk, and the strength

of this base is encreased by the plantigrade position of the whole foot, the parallelism and magnitude of the inner toe, the advanced position of the astragalus, the extension backwards of the tuberosity of the calcaneum, the fixed condition of the tarsus, and the strength of the meta-tarsal bones, and the phalanges of the toes.

CHAPTER SECOND.

ORGANS OF ATTACHMENT, OR LIGAMENTS.

The solid parts of the skeleton, whether external or internal, are held in connexion and are allowed to move on each other with more or less freedom, by means of soft parts, which are almost as inert in their vital properties as the bones themselves, and this low degree of vitality better enables them to sustain the stretching and compression to which they are continually subjected. Even in the highest animals the ligaments which connect the bones, and the cartilages which bound their contiguous sufaces, are scantily supplied with blood-vessels and nerves, and have a corresponding low degree of sensibility, great slowness of growth and reproduction, and great tenacity of life. In the lowest tribes the component pieces of the skeleton are held together by the simplest mode of union, they have not their points of contact protected by a layer of soft cartilage, lubricated with synovia, and connected by capsular ligaments and external ligamentous bands, they are partially or entirely imbedded in a common tough connecting matter, which, by its elasticity, admits of the few required motions. No articulations nor ligaments appear in the soft, gelatinous,

transparent bodies of the animalcules, but in the poripherous animals the dense silicious and calcareous spicula which compose their solid frame-work are supported and maintained in their positions by a more tough, elastic and firm portion of the general cellular tissue of the body, perhaps stimulated to condensation by the presence of these earthy crystalline bodies. By the motions of the body, produced by external bodies, the points of these sharp spicula are made to project from this tough connecting matter in various directions from the gelatinous surface of the body, from the margins of the pores, or into the internal canals. The tubular filaments in the horny species anastomose with each other freely throughout the whole body, like the continuous connecting matter in the earthy species. The jointed appearance seen in most flexible tubular keratophytes, as *sertulariæ, plumulariæ, campanulariæ*, is confined to the exterior covering, and does not interrupt the course of the fluids circulating through the enclosed fleshy part. These thinner portions and annular strictures of the horny covering allow of the more ready development of new branches, cells, or vesicles, and of the incessant movements of all their parts produced by the ever-restless sea. The branches of the *cellaria thuya* drop off regularly from below upwards along the stem, at these apparent joints. The minute calcareous spicula of many corticiferous and fleshy zoophytes, as *gorgonia* and *lobularia*, are connected by the general cellular substance of the body. The black, flexible, elastic matter deposited in concentric layers between the calcareous internal solid pieces of the *isis hippuris*, are merely uncalcified portions of the common animal matter which pervades the whole skeleton, and connects all its earthy particles; they are like the uncalcified portions of *corallinæ*, but are secreted, as the calcareous matter of the skeleton, by the enveloping fleshy crust. The exterior sharp spines of *pennatulæ* are connected and moved by the coriaceous irritable skin of the body. The skeletons of zoophytes, as those of higher testaceous animals, are insinuated into the minutest inequalities of the surface of rocks, and thus adhere firmly, by being exuded in a soft semi-fluid state, and then condensing. The cartilaginous, internal, reticulate filaments of many *alcyonia* are continuous, like those of horny poriphera, throughout

the whole body. Broken fragments of the solid skeletons of zoophytes are readily re-united by the exudations from the fleshy substance, of similar ossific matter around the broken extremities, as we see in the testaceous extravascular coverings of higher classes. The delicate vertical, crescentic lamina of the *velellæ* is continuous with the more thick horizontal plate on which it rests, and is not detached by maceration. The moveable, lateral, solid plates of the stellerida are connected both by irritable and ligamentous bands, as are also the solid jointed moveable spines frequently developed on their upper surface. The plates composing the shells of the echinida are united by harmonic sutures, and the spines are united to the tubercles by the enarthroid form of articulation, where there are marginal muscles, an exterior capsule, and generally a round central ligament, like the ligamentum teres of the femur, as in the cidaris and spatangus. The unconsolidated portions of the general cuticular exudation form the means of connection between the dense external parts of the trunk and its appendices in the helminthoid and in the entomoid classes of diplo-neura. This we already find in the segments of the trunk and of the rudimentary antennæ of some of the higher *epizoa*, in the tough epidermic membrane connecting the pieces of pedunculated cirrhopodous shells, and in the segments and cirrhi of the same animals, and of many of the higher annelides. In the more solid skeletons of the entomoid classes, the calcified coverings of the segments of the trunk and of the antennæ and palpi are partially retracted within each other, and are connected by numerous muscles, and by the true skin, and its continuous thin epidermis. The other appendices developed from the sides of the body present chiefly the ginglimoid forms of articulation without the aid of ligaments, where one portion of the skeleton is locked into another, and where the motions of the joints are very secure, but limited in extent; these forms of the articulations we see especially in the strong members of the larger crustacea and coleopterous insects. The valves of conchifera are connected together both by the teeth of the hinge, which are often locked into each other, as in *spondylus*, and by the tough extra-vascular *ligament*, which grows by successive layers of epidermic matter, and constantly

tends by its elasticity to separate the two valves between which it is placed. The eight transverse plates composing the shell of the chitons have generally a strong coriaceous ligamentous band connecting their margins, and secreted like the ligaments of conchifera, by the surface of the skin. The byssus of conchifera consists of horny filaments secreted in a fluid state by a gland behind the base of the foot; they are conveyed along a median groove of the foot, to be attached to external solid bodies, to anchor the more delicate shells, as *pinnæ* and other mytilacious bivalves. The horny operculum of most of the testaceous turbinated gasteropods is of a condensed albuminous nature, secreted in successive superimposed layers added to the attached surface by the muscular foot, to which it adheres in the same manner as the retractor muscle adheres to the columella of the shell. From the ginglimoid hinge of the shells of conchiferous mollusca admitting only of flexion and extension in one direction, few, though powerful, muscles are required to effect their motions; but the joints of the articulated classes of animals being generally formed by a segment of one sphere being enclosed within another, and consequently admitting of rotation in every direction, numerous muscles are required to effect their varied movements. The ginglimoid crural joints of the entomoid classes being formed by hollow, cutaneous, solid tubes, have generally one very strong and broad flexor tendon, and a more narrow and feeble extensor tendon, into which all the muscles of the joint are inserted, and they are deeply excavated and covered only by the unconsolidated, thin, tough epidermis and skin on the side to which the joints are inflected. There are no opercula, or moveable pieces of the shells in the *pteropoda* or *cephalopoda*, and the soft cartilaginous, organized, internal bones of the cephalopods are connected only by muscles, and by thin unconsolidated portions of their own soft matter.

In the soft, flexible, cartilaginous skeletons of the lowest cyclostome fishes, there are scarcely any traces of articulations or ligaments, and in the higher chondropterygii they are almost confined to the most moveable parts connected with mastication, and the fins for progressive motion. In fishes, as in the inferior classes, where the skeleton becomes more consolidated by earthy depositions, the articulations

and ligaments become more developed and distinct. The vertebral ligaments of osseous fishes are white, fibrous, and dense in their texture, and by their elasticity they bring back forcibly the vertebral column to the straight position when it has been drawn to either side by the lateral strata of muscles. The moveable intermaxillary, palatine, and superior jaw bones are connected by a tough fibro-cartilaginous membrane, as well as by muscular attachments. The moveable articulations of fishes are mostly effected by a tough interposed cartilage, which envelopes the contiguous ends of the bones. This substance is much softer than the corresponding fibro-cartilaginous parts of higher classes, and is more readily dissolved by boiling water. In place of the interposed elastic sacs between the cup-like cavities of the vertebræ of fishes, or the firm connecting layer of fibro-cartilage between the vertebræ of mammalia, we find the bodies of the vertebræ of reptiles united by distinct moveable articulations, or enarthroses, with strong capsular ligaments and synovial secretion, and many of the vertebræ of birds, especially of the neck, are united by the same free and secure articulations. In the amphibia and in the reptiles, most of the articulations are constructed on a simpler plan than in the warm-blooded classes ; there is yet no inter-articular cartilage between the condyle of the lower jaw and the temporal bone, nor a ligamentum teres between the femur and the cotyloid cavity ; but the articular surfaces of the long bones are covered with smooth and firm cartilage, are lubricated with synovia, and are enclosed in strong capsular ligaments. The articular processes of the vertebræ have here their synovial capsules, and the spinous processes their inter-spinal ligaments. The articular cavities of the joints are less deepened by cartilaginous margins, the internal loose cartilages of the joints are more rare, the exterior ligamentous bands are more simple in their arrangements, and there are fewer immoveable synarthroses than in birds and mammalia. The capsular ligaments are thinner, and of a more dense texture in birds than even in mammalia, and more synovia is poured into the joints, especially of the neck and extremities, on account of the extent and rapidity of their movements and the high temperature of their body. Each end of the tympanic bone is here enveloped in its

synovial capsule, although most of the cranial bones have lost even their connecting sutures, and most of the vertebræ have their bodies united by free and secure synarthroses. Less pressure being exerted on the joints in the light bodies of birds than in the heavy bodies of mammalia, there is a much thinner layer of elastic cartilage on the contiguous ends of their bones than in quadrupeds, and from the lightness of their head, as in other oviparous vertebrata, compared with that of most quadrupeds, they have no necessity for a ligamentum nuchæ to support it. The thick, firm, elastic layer of fibro-cartilage interposed between the flat bodies of the vertebræ of quadrupeds is the mode of articulation which best corresponds with the strength and the slow and limited motions required in that region of their skeleton. The synovial capsules of the articular processes of the vertebræ are more developed in the active trunks of carnivorous and of climbing mammalia than in the more weighty and motionless bodies of pachyderma and ruminantia. The long anterior and posterior vertebral ligaments are of great strength and elasticity along the pliant columns of cetacea without and within the spinal canal, and in the long and pliant tails of many quadrupeds we find the highly moveable bodies of the coccygeal vertebræ united by synovial capsules, to facilitate their motions. The heavy-headed herbivorous quadrupeds have the ligamentum nuchæ of great size and strength, extending from the occipital protuberance along the spinous processes of the dorsal, and often of all the succeeding vertebræ to the coccygeal, sending a pair of laminæ downwards to be attached to each spinous process. In the light-headed and muscular carnivorous species this ligament is very small, and generally extends forwards only to the large spinous process of the axis, and in many of the most active rodent and quadrumanous mammalia, no trace of this cervical ligament is perceptible. In the strong extremities of heavy herbivorous quadrupeds, where limited motions and secure articulations are required, the capsular ligaments are less loose and elastic than in the carnivora, where greater freedom and extent of motion are necessary, and greater force of action. Strong transverse ligaments pass in the elastic feet of ruminating quadrupeds from the one penultimate phalanx to the

other, to prevent the tearing of the two toes asunder during their rapid and bounding movements, which are not compatible with the extensive movements of the toes of carnivorous species. In the slow-moving extremities of the elephant, the rhinoceros, and the hippopotamus, there is no ligamentum teres to fix the head of the femur to the cotyloid cavity, nor do we find it in the kangaroo, the sloths, or the monotrema, nor in the sedate orangs, which so much approach the human species.

CHAPTER THIRD.

ON THE MUSCULAR SYSTEM, OR ACTIVE ORGANS OF MOTION.

FIRST SECTION.

General Observations on the Muscular System.

THE movements of animals are effected by the muscular system, the most remarkable and essential property of which is the power of contracting with rapidity and force on the application of stimuli. The fibrous structure is not a constant character, nor essential to the irritability of this system, although that vital property is greatest in all the higher classes, where this structure prevails. These irritable fibres appear to consist of lineal aggregates of fibrinous globules, the union of which is most intimate where the contractile power is greatest. The cohesion of these globules is least where all lineal arrangement is lost, in the lowest tribes of animals, in which the slowly irritable fleshy substance appears as a soft, homogeneous, cellular tissue. The muscular system effects all the locomotions of animals, and all the movements of their organs of relation, and forms

a constituent part of all the active organs of vegetative life ; so that the consideration of many parts of this system is inseparable from the history of particular organs. The contractity of the muscular fibre is intimately connected with the extent of respiration in animals, being feeble in the radiated and molluscous tribes, where the respiration is small, and more energetic in the articulated classes, where the respiration is greater, and generally aerial, and for the same reason it is less powerful in the imperfectly aerated reptiles than in the feathered tribes where the air permeates every region of the body. It is by means of this system that animals are enabled to move to and fro, to seize and masticate their food, or to convey it through their alimentary cavity, to circulate their fluids through the body, to force all discharges from their system, to bring the surrounding element into contact with their blood, to produce various sounds for mutual intercourse, and to vary to infinity the outward form and expression of their body ; the different parts of this great and complicated system can therefore be classified and arranged according to the functions to which they are most subservient. The movements of *voluntary muscles* appear to be accompanied with a distinct perception of their active state, and to become associated with feelings of the mind ; so that they chiefly belong to the organs of relation, or the functions of *animal life*, while those of the *involuntary* muscles, unaccompanied by sensations, and more independent of the rest of the body, are chiefly connected with the organs and functions of *vegetative life*. In most muscles the component fibres run parallel to each other, with numerous minute nervous fibrils and capillary blood-vessels running in the same longitudinal direction between them, and freely anastomosing to produce a complicated net-work throughout the whole texture. Although the muscular fibres are organs distinct in their whole course, they are united into fasciculi, and these into entire muscles by means of cellular tissue, and they are generally inserted into strong, tough, fibrous tendons, which are less supplied with nerves and blood-vessels than the muscles themselves, and are destitute of irritability. The muscles of the highest classes of red-blooded animals, during their development, pass through the soft, colourless, homogeneous, and gelatinous condition

of those of the lowest animals, before they assume the red colour, the dense fibrous structure, and the highly irritable and contractile property, which they possess in their mature form.

SECOND SECTION.

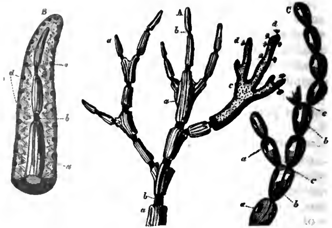
Organs of Motion in the Cyclo-Neurose, or Radiated Classes.

Although the aid of the microscope has not enabled us to detect muscular fibres in the transparent and active bodies of the polygastric animalcules, most of them exhibit distinct signs of lively irritability in contracting bending and stretching their whole body, or its anterior prehensile part; and they are carried rapidly to and fro in their dense element by the rapid vibration of minute cilia generally disposed in regular series on their external surface. The cilia are the organs of respiration, as well as of locomotion in these animalcules, and they are generally longest and largest on the anterior part of the body, especially around the mouth, and in the flat forms, as the *cyclidium*, the long cilia form a vibratile zone around the inferior margin of the body. Where the anterior part of the body is obliquely truncated, as in many of the *kolpodæ*, the vibration of the cilia gives a revolving motion to the whole body in its progression. In most of the *trichodæ* and *paramæcia* the cilia are disposed in regular close longitudinal series extending over the whole outer surface of the body, and of the greatest length around the oblique mouth. The *vorticellæ* have two rows of cilia disposed around their anterior circular extremity. The cilia have been observed in almost every class of animals from the polygastrica to the mammalia, and both on the surface and in the interior of the body; but the means by which they are moved have not been detected. No cilia have been seen in the spermatic animalcules, which are extremely minute and are moved by the lateral motions of their slender tail, like tadpoles, which implies greater irritability and muscular development than in the ordinary polygastrica.

The action of vibratile cilia is always so much independent of the will, or connection with the rest of the body, that it continues for some time after the part to which they are attached has been severed from the animal; and this is observed even in those of adult birds and quadrupeds. Jaws containing sixteen teeth have been detected in the *loxodes cucullulus*, which necessitate great muscular development in this minute polygastric animalcule.

The soft cellular tissue which pervades the whole fibrous texture of poripherous animals, and lines their pores, canals, and vents, does not exhibit distinct signs of irritability or contractility when acted on by the strongest stimulants, and the currents continue to be impelled rapidly through these passages even in thin portions cut from the body. It is probable, therefore, that the currents are produced solely by means of cilia which are numerous and large over the surface of these animals, when in the state of gemmules newly detached from the parent. The ciliated free gemmules of poriphera do not exhibit signs of irritability by contracting their body, and changing their form like those of zoophytes. The cellular substance of the poripherous animals, being still of a soft and semi-fluid consistence, is incapable of effecting any perceptible movements in the fibrous skeleton which it permeates. The general fleshy mass of the body possesses distinct though languid irritability in almost all forms of zoophytes, although the fibrous structure is seldom developed in any part. This property is manifested in the *lobularia* by the spontaneous slow contraction and dilation of its body at different periods of the day by the influence of temperature and light, or by the slow contraction of a part of the body which has been touched or irritated. This fleshy contractile part is the same which secretes the solid matter of the skeleton in this class, and developes the polypi from different parts of its surface. The relation of this irritable and secreting part to the internal axis in the corticiferous zoophytes is seen in the section of the *isis hippuris*, (Fig. 62. B.) where the calcareous solid portions (*a*,) and the flexible, elastic, ligamentous parts (*b*,) occupy the centre of the fleshy substance (*c*,) and the cells of the polypi (*d*, *d*,) are seen to be here confined entirely to this irritable crust, and to leave no impression on the axis. The polypi are the

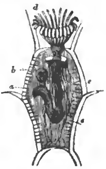
FIG. 62.



most irritable and contractile parts of the body in all zoophytes, and the most exquisitely sensitive to external impressions. The polypi are prehensile sacs or mouths developed from and continuous with the fleshy substance of zoophytes, their margin is surrounded with delicate fleshy arms or tentacula, which vary in different species from six to more than thirty. The polypi are seen extended from the fleshy substance of the *isis* in Fig. 62. A. *d, d,* the fleshy part covers the branch at (*c*,) and is removed from the jointed skeleton at (*a, a, b, b*.) The fleshy part of the *isis* appears to be incapable of bending the joints of the skeleton, and it has as little effect on the skeleton in the other corticiferous zoophytes. Where it forms thin laminæ consolidated with calcareous matter, and disposed around the parietes of cells, as *flustræ*, *escharæ*, and *cellariæ*, it is as little capable of moving the axis. In the *cellaria loriculata* (Fig. 62. C,) where the cells of the polypi (*a, a*,) are disposed in regular consecutive pairs with their apertures opposite, and with contracted articulations (*c, c*,) at the bases of the cells, neither the enclosed polypi, nor the fleshy part of the entire animal are capable of bending the articulations. The slow contraction of the *pennatula phosphorea* coils up the thin flexible extremities of its calcareous

axis, and moves the retroverted spines of its exterior surface so as to push the animal slowly along a rough surface. In the vaginiform zoophytes the internal currents of the body are not produced by the contractions of the internal fleshy parietes, though compared by Cavolini to a heart, but by the action of vibratile cilia, and the open base of the polypi often contracts, as if by a movement of deglutition. The polypi being the organs by which the food is attracted, seized, and digested, and the surface of the body aerated, they possess the most complicated structure and the highest vitality. The tentacula surrounding the mouth, as in the *flustra carbesia* (Fig. 63. *d*,) have generally minute vibratile cilia disposed along their sides, by the action of which currents of water conveying animalcules and other food, are directed towards these prehensile and digestive cavities. In these complicated and highly irritable polypi of the *flustra*, we perceive numerous muscular bands (Fig. 63. *c*,) connecting the lower part of the polypus with the aperture of the cell, and others passing from the same part of the polypus downwards, to connect it with the bottom of the cell (*e*.) The vibratile cilia move the currents outwards along one side of each tentaculum (*d*,) and inwards along the other side, and they are generally visible only while they move in the direction of the currents which they produce, that is in their forward stroke. When in full activity the cilia are invisible in their backward movement, from the velocity with which they resume their position, to commence a new stroke forward. And as vibratile cilia are thus generally perceptible only in their slow forward impelling movement, they have some resemblance to a stream of globules flowing always in one direction. There are about fifty cilia on each side of a tentaculum in the *flustra carbesia*, and nearly forty millions on a moderate specimen of the entire animal. In many zoophytes they are much more numerous ; so that these fixed and plant-like animals, though possessing a very low degeee of irritability in their general mass, are well provided with active organs

FIG. 63.



to bring their food towards them, and to renew the stratum of water in contact with their surface, for the purpose of respiration. The vibratile cilia are generally disposed around the mouth of the polypus where the cilia of the tentacula themselves are not vibratile, but merely lateral extensions of these prehensile organs. The naked hydræ are irritable and contractile in every part of the body, and their texture appears cellular throughout, without any distinct muscular fibres. The fibrous structure is partially developed in the irritable parts of some of the larger and more complicated polypi, as those of the *pennatula*, *virgularia*, and *lobularia*, and they form distinct longitudinal and sphincter bands in the *actiniæ* and in the polypi of some of the larger lithophytes, as *fungiæ*, *explanariæ*, and *caryophylliæ*, which so much resemble fixed actiniæ.

Many of the acalepha swim, like animalcules, by the movement of external, longitudinally-disposed, vibratile cilia. These cilia are large, and generally visible by the naked eye, and are distinctly supported by parallel rays, like the fins of a fish; but the muscular apparatus by which they are so rapidly vibrated is not perceptible. From the development of the nervous system, and even of eyes containing a crystalline lens, seen in some of the animals of this class, it is probable that the parallel fibrous striæ perceptible in the highly contractile mantle of medusæ are of a muscular nature. The long tentacular filaments which we so frequently find developed from the periphery of the mantle possess a high degree of irritability, and are exquisitely sensitive. The muscular development is less required in the hydrostatic or physograde species, which are supported at the surface of the sea by an air-bag, or a sac filled with a gaseous secretion due to its own parietes. The large pectinated cilia of the ciliograde acalepha have the same kind of rapid vibratile motion as the minuter forms of these organs seen in zoophytes and animalcules, and they continue in the same manner their movements independent of the rest of the animal in parts severed from the body.

The fixed crinoid echinoderma appear to move their numerous calcareous articulations by the exterior irritable and secreting fleshy covering which envelopes all parts of their body. In the free stellerida the nervous and the mus-

cular systems are already obviously developed, and eyes are observed on the asterias. The segments of many of the stellerida are connected together and moved by muscular bands, which are distinctly fibrous, and both longitudinal and circular fibres are seen on the highly irritable and contractile feet, which extend from the ambulacra. The same muscular structure is seen in the long tubular prehensile feet of the echinida, where the segments of the trunk are immoveably united by harmonic sutures. Strong adductor and abductor muscles are seen attached to the moveable pieces of the jaws in many of these species, and strong muscular fasciculi pass from around the base of the external spines to the periphery of the tubercles on which they move. In the naked holothuriæ, the tough, exterior, coriaceous covering is highly irritable and contractile; these animals are provided with five crowded longitudinal rows of the usual tubular, muscular, prehensile feet extended like those of other echinoderma by the injection of water into their median cylindrical cavity; their dental apparatus is provided with its muscular bands, and the five larger of these osseous plates around the mouth give attachment to five strong longitudinal muscular bands which extend beneath the skin to the posterior extremity of the body.

THIRD SECTION.

Muscular System of the Diplo-Neurose, or Articulated Classes.

The development and energy of the muscular system are greater in the articulated than in the radiated, or even the molluscous classes, which corresponds with the greater extent of their respiration, and with the higher condition of all their other organs of relation. In the subcutaneous muscular tunic of the nematoid entozoa, we already perceive the longitudinal and transverse short interrupted filements, which are more symmetrically arranged into bands and muscles, where the segments of the trunk are more consolidated and

distinct in higher classes. In the outer layer of this muscular coat, the short interrupted and interlacing fibres have a transverse direction, and those of the same kind forming the inner layer have a longitudinal direction, and are generally grouped to form four lengthened contractile bands; the longitudinal fibres compose distinct muscles, especially at the anterior part of the body where they are attached to the moveable parts of the mouth. The muscular fibres are not perceptible and the irritability is most feeble in the cystoid and cestoid forms of this class. The long pliant organs of attachment by which the entomoid forms of these entozoa adhere to the surface of aquatic animals, present generally distinct longitudinal muscular bands, as we see in *lernææ*, and they are also developed for the movement of the maxillæ and other dense, and articulated parts of their body.

The muscular apparatus is most distinct and complicated in most of the rotiferous or wheel animalcules, and corresponds with the high development of their nervous and other important sytems. There are numerous fasciculi at the anterior part of the body, for the movement of the long vibratile cilia which surround the mouth; the maxillæ are enveloped and moved by a strong muscular apparatus, which can be deeply rctracted within the body by longitudinal bands, and similar longitudinal bands extend along the whole internal parietes of their body for the retraction and bending movements of the trunk. The muscles of these animals, though most distinct, are almost as colourless and transparent as the crystalline parietes of their body. They are carried through the water by a slow and gliding movement, produced by the rapid vibration of the long cilia which surround the anterior parts of their body, and these cilia while in action, appear like a revolving wheel from their forward, slower and more forcible movement being alone perceptible by the eye. The currents of water and the surrounding particles move in the same direction in which the circles appear to revolve.

In the cirrhopods we find united in the same animals, both the articulated and the molluscous forms of the muscular system, and these are accompanied with a fixed condition of the exterior shell, and a high activity of the enclosed

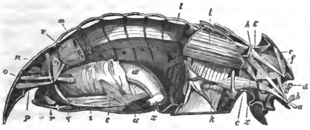
animal. The peduncle and the mantle present distinct musclar fibres, the dorsal part of the abdominal cavity near the head, is attached by several muscular fasciculi to the mantle and the shell, and a strong adductor muscle, as in bivalves, passes straight across from one moveable piece to the opposite. The fleshy parietes of the abdominal cavity, the conical tubular funnel prolonged from that cavity, and the haunches and innumerable tubular articulations of the cirrhi present distinct muscular fasiculi. In the pedunculated forms, as in the *pentalasmis*, the whole of the convex dorsal part of the enclosed animal, is covered with crossing muscular fibres, which pass off in numerous separate fasciculi to be attached to the inside of the proximal, or closed part of the enveloping multivalve shell; these draw the animal forcibly and quickly back into the shell after its body has been protruded for respiration or for food. The haunches of the jointed members, and the base of the funnel-shaped tube, also receive distinct muscles from this fleshy dorsal part of the cirrhopod for their varied movements.

The annelides generally present a distinct muscular tunic of a complicated structure immediately beneath the outer tough and annulated integument, and intimately united to it, besides the muscular fasciculi appropriated to the motions of the lateral setæ and cirrhi which extend from muscular sheaths. This subcutaneous muscular tunic is resolvable into distinct layers, and each of these into innumerable separate fasciculi; the most exterior of which have generally a transverse or an oblique direction, and the most interior a longitudinal course, as seen in the same part of the entozoa. These longitudinal muscles are more or less distinctly divided into longitudinal bands, as those of the nematoid entozoa, and as we see even in the holothuria, the actinia and many other of the radiated animals. This muscular tunic of the annelides appears to act on the interior viscera, as well as on the external imperfectly developed segments. Its exterior layer is sometimes double, the one portion consisting of oblique fasciculi and the other of tranverse, and both of these exterior to the usual internal layer of longitudinal fasciculi. The several muscles are disposed similarly in the different seg-

ments of the same worm, and even in different worms, in the larvæ of insects, in myriapods, and in the segments of the trunk of most of the articulated classes of animals. In the common earth-worm, as in many others, the muscular sheaths for the extention and retraction of the short conical curved and pointed feet consist chiefly of radiating fibres which extend from around the base of these hollow spines. The fleshy lips of this animal are provided with several longitudinal and circular muscles appropriated to their varied movements, and the anus is distinctly furnished with levator and spincter muscles.

From the aerial respiration and the higher general development of most of the entomoid articulata their muscular fibres are more dense and irritable, and from the greater consolidation and distinctness of their segments, their muscular fasciculi are more isolated and more methodically disposed, than in the softer trunks of the aquatic helminthoid tribes. The myriapods, like the worms, having their segments and their lateral appendices equally developed from the one extremity of the trunk to the other, without distinction of thorax and abdomen, present the greatest similarity in the muscular system throughout all their segments, and the greatest resemblance to the disposition of that system in annelides and in the larvæ of insects. More than four thousand distinct muscles are found in the larva of the common cossus ligniperda, and these are disposed in concentric strata, the fasciculi of which are directed, some longitudinally some transversely, and others with various degrees of obliquity, passing, as in the trunk of most adult entomoid animals, from the concave inner surface of one segment, to the anterior enclosed margin of the next succeeding. As the extremities and wings for progressive motion become developed from the thorax, the muscular apparatus of that portion of the trunk becomes more developed than in any other segments. In the annexed figure from Straus, representing the principal muscles of the trunk of the male cock-chaffer, *melolontha vulgaris* (Fig. 64,) we observe that the interior layer of muscles of the segments of the abdomen (*l*,) run in a longitudinal direction, like those of the helminthoid classes. The muscles of the abdominal segments consist generally of parallel short fasciculi, which retain the same

FIG. 64.



breadth and form from their origin to their insertion; but in the anterior part of the trunk, where the movements are more powerful, the muscles have generally a conical form, being broad at their origin, and tapering towards their point of insertion; so that more muscles can be inserted into a limited point, to strengthen and vary its movements. This form is seen in the depressor muscle (*a*,) of the head, and in the lateral flexor (*b*,) of the same part. The fasciculi of the rotator (*d*,) of the head are more parallel, but they converge to a point in the two portions of the levator capitis (*e*, *g*,) and in the inferior (*c*,) and the superior (*f*,) retractor of the corselet, the levator (*x*,) of the corselet, and the levator obliquus (*h*,) of the jugular piece. The fasciculi are more parallel in the large and powerful depressor muscle (*i*,) of the wing, on which the flight of the insect so much depends, and also in the several portions of its broad levator muscles (*k*.) The same tapering and pointed form is seen in most of the muscles in the region of the pelvis, or attached to the moveable pieces of the anus, as in the strong levator (*n*,) of the inferior anal piece, the retractor preputii (*q*,) the posterior retractor (*p*,) of the inferior anal piece, and the retractor of the cloaca (*o*.) There is also great uniformity observed in the disposition of the flexor and extensor muscles in the ginglimoid articulations of the legs in all the entomoid classes, and in the more moveable rotating articulations of the antennæ and palpi of these animals. The muscles of the trunk in these highest articulated classes, like those of the helminthoid forms, are still divided into bands, which occupy chiefly the dorsal and the ventral aspects of the body, and these are again partially divided

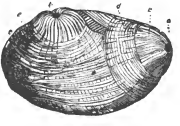
on the median plain by the dorsal vessel above, and the nervous columns below; and here, as in the vertebrated classes, we observe that these symmetrical and voluntary muscles do not cross the median plain of the body. They are connected through the medium of the skin to the solid coverings of the segments; so that the exuviable skeleton is cast off in all these entomoid classes without affecting the insertions of the muscles into the true skin. In the air-breathing, pulmonated and tracheated arachnida we find the same dense, irritable, and serrated character of the muscular fibres as in the perfect insects, a similar structure of the muscles and their tendons, and the same general disposition of these organs where the articulations resemble. Their capaceous cephalo-thorax is occupied chiefly with the large and strong muscles of the haunches of their numerous long legs, and with those of their masticating and poisonous apparatus. The long cylindrical segments of the post-abdomen of the scorpions are chiefly occupied with the powerful muscles appropriated to the movement of the poisonous sting formed by the last segment of the trunk. The tendons of the muscles here, as in insects and crustacea, are only calcified prolongations from the exterior skeleton. The muscular system of the crustacea forms a larger proportion of their body than in the air-breathing articulata, and their movements are more rapid and powerful than in almost any other branchiated invertebrata; their individual fibres, however, are softer, more white and pellucid, less compact in their texture, and less irritable and strong, than in the pulmonated or tracheated classes; and they require less muscular force on account of the support which they receive from the density of the element through which they move. The muscular apparatus of their external organs of mastication and of locomotion closely resembles that of insects, but their stomach is covered with powerful muscles for the movement of the internal teeth with which it is provided; the ventral portion of their post-abdomen is furnished with numerous and strong muscles for the movements of that part of the trunk in swimming, or for its retraction when alarmed; and the muscles of the prehensile terminal parts of their legs, especially of the anterior pair, are proportionally large and strong for the contests in which they are continually engaged.

FOURTH SECTION.

Muscular System of the Cyclo-Ganliated, or Molluscous Classes.

The limited extent and the aquatic nature of the respiration in most of the molluscous classes, and their fixed condition, or imperfect means of locomotion, are accompanied with a corresponding low degree of vitality and imperfect development of their muscular system. The forms also of this system, as of the whole body, vary much more in this than in the articulated or vertebrated divisions of the animal kingdom. Within the exterior cartilaginous covering of the tunicated animals is placed their muscular coat by which they are able to contract their whole body, and forcibly to expel the contents of their respiratory or thoracic cavity. This muscular enveloping tunic, as seen in that of the *cynthia pupa* (Fig. 65,) consists chiefly of long diverging fasciculi which originate from around the two orifices of the sac (*a. b,*) and extend round the whole body of the animal. These muscular fasciculi are attached to various points of the exterior tunic, but most intimately around the respiratory (*a,*) and the anal (*b,*) orifices, which we observe also to be provided with distinct and strong sphincter muscles (*d, e,*) passing in a circular manner around them. By the contraction of the whole of this muscular tunic, the orifices are

FIG. 65.



retracted, the trunk of the animal is compressed, the respiratory cavity is emptied, and the whole body is retracted towards the fixed point to which the animal is attached. The respiratory currents are produced by the vibratile cilia disposed on the branchiæ, and on the thoracic cavity, as in other acephalous mollusca, and the swimming of some of the aggregate forms, as of the pyrosoma, is effected by the same respiratory currents produced by vibratile cilia. The muscular coat of the tunicata is analogous to the mantle of bivalves, as their cartilaginous covering is the analogue of the shell.

The conchiferous animals are much more generally free than the tunicata, and some of them possess considerable power of locomotion. The movements are chiefly performed by the foot, which is commonly a lengthened tongue-shaped, muscular organ, capable of being protruded to some distance from the cavity of the mantle, and capable of assuming a great variety of forms. By this organ the conchifera attach their byssus, swim at the surface of the water, creep on a solid surface, burrow in sand, or other soft material, and extricate themselves when covered. The foot is composed of muscular fasciculi, which decussate each other in various directions to give it great variety of movements, and water is often admitted into its interior cavity. It is sometimes wanting where the shell is permanently fixed to a spot, as in the oyster. It is generally more or less connected with the dorsal part of the valves, and the fibres of its expanded base embrace almost the whole of the abdominal cavity. The adductor muscles are the active organs by which the valves are closed against the elastic property of the ligament, and they generally consist of one or two thick, short, and strong muscles, which pass straight across the ventral surface of the abdomen, to be attached to the inner surface of both valves. The pecten is enabled to swim backwards by the powerful and repeated action of its adductor muscle on the valves.

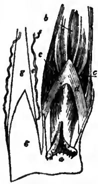
The adductor muscle is large and single in most of the round forms of conchifera, as the pecten, ostrea, anomia, spondylus, but in the more lengthened forms there are

generally at least two. This muscle passes through the pierced valve of anomia to be attached to some external body. Between the two muscular impressions of the *dimyaria*, there is commonly a rough groove on the valves running near the ventral margin, and seen in the corresponding situation in the *monomyaria*, which indicates the place of attachment of the fibres of the palleal muscle, by which the projecting free margins of the mantle are retracted into the shell. This marginal muscle consists of numerous small fasciculi attached along this groove in both valves, and spreading chiefly on the loose ventral margins of the mantle. By forcibly retracting this part of the mantle, these palleal muscles contract the respiratory sac, so as to assist in a forced expiration of the contained water, and they protect the most sensitive marginal part of the mantle from being compressed and injured during the closing of the valves. The currents of water which are conveyed into the cavity of the mantle through the respiratory orifice, and outwards through the vent, for the purposes both of respiration and nourishment, are entirely produced by the rapid action of vibratile cilia, which are disposed in the closest arrangement around all the minutest meshes of the branchiæ, and cover all the fringed edges of the respiratory orifice and nearly the whole inner surface of the respiratory cavity of the mantle. As all other vibratile cilia, these continue in lively activity on portions of the gill or mantle which have been long cut from the body of the animal. The respiratory cavity of the mantle, with highly contractile muscular parietes, is often prolonged to a great distance beyond the margin of the valves, especially in burrowing species, to reach with the respiratory and anal orifices, the surface of the bed or rock in which the animal is concealed. Besides the usual large adductor muscles, there are frequently smaller supplementary transverse muscular bands passing from the dorsal part of one valve to the other.

The muscular foot of the gasteropods sometimes covers the whole ventral surface of the body, and sometimes extends only from the under surface of the neck; it is the largest muscle of the body, and that by which progressive motion is effected both in creeping and swimming. In the inhabitants of turbinated shells or the trachelipodous gas-

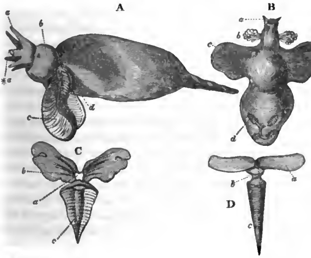
teropods, the muscular fibres of the foot extend upwards along the neck, and a strong fasciculus is prolonged backwards under the body to be attached to the columella of the shell. This retractor muscle forms the only bond of connection between the shell and the animal it contains, and it is constantly advancing slowly along the pillar of the shell during growth like the adductor muscles of conchifera. The open mantle which secretes the calcareous matter of the shell is also distinctly muscular and contractile, and the funnel for respiration is an open canal prolonged from its left side. The foot is often expanded by the introduction of water into its interior cavity, and its dorsal surface secretes the calcareous or horny layers which compose the operculum of the shell. The neck forms generally a thick muscular sheath around the complex apparatus of the mouth and proboscis, and supports on the right side the muscular exciting organ of the male; anteriorly it forms the lips or the sheath of the proboscis, and the tentacula which have generally the eyes at the exterior of their base. In the naked gasteropods found generally adhering to floating plants in the ocean, as the *scyllæa* and *tritonia*, the foot forms a long narrow groved organ for embracing the tender stems to which they adhere, and on which they feed. Most of the predaceous gasteropods possess a long and powerful muscular proboscis capable of being extended to a distance from the mouth, and provided at its extremity with an exsertile bifid fleshy tongue armed with sharp conical recurved teeth, as seen in that of the common whelk, *buccinum undatum* (Fig. 66.) Both the proboscis *(g, g.)* and the enclosed bilabiate spiny tongue *(a, b.)* are provided with numerous powerful extensor and retractor muscles contained in the neck. The two divisions *(a.)* of the tongue to which the teeth are attached are often supported internally by two long cartilaginous laminæ, large and strong in the *buccinum*, which appear to be the analogues of the gastric dart of conchifera. The phytophagous gasteropods have generally jaws for compressing their vegetable food, or a long spiny tongue for filing it to pieces.

FIG 66.



The muscular system of the pteropods, like that of many of the floating gasteropods, is generally soft, transparent, and nearly colourless ; so that the disposition of the fibres in the exterior closed mantle, and in the fin-like arms can be perceived through the outward pellucid coverings of the body. Having no muscular foot for creeping, their progressive motion depends on the movement of two muscular membranes, unsupported by rays or by cartilage, and extending from the sides of the body. These muscular fins are developed both in the naked and the testaceous forms, they present the most favourable situation for the branchiæ which are generally placed on their surface, and they sometimes serve as organs of prehension, embracing the surface of plants, and other objects floating through the sea. The muscular mantle, closed above, forms a large abdominal cavity, and its contractions assist in expelling the natural excretions of the viscera, or in retracting the whole body within the shell. The tentacula also, and the whole apparatus of the head, are retracted and extended by their own muscular fibres, and the œsophagus is sometimes provided with a distinct muscular bulb, like many gasteropods. The annexed figure, (Fig. 67,) represents two naked and two testaceous forms of *pteropods*,

FIG. 67.

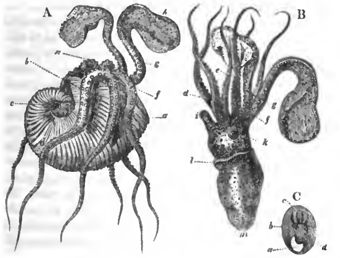


with their muscular organs of motion extended laterally from the sides of the trunk, and placed more anteriorly than those of the naked cephalopods. In the *clio australis*, (Fig. 67, A) the form approaches very closely to the cephalopodic in the numerous conical, tubular, cephalic tentacula (A, *a*, *a**,) the form of the head (*b*,) the position of the eyes, and the lengthened cylindrical form of the trunk, enveloped in a closed muscular mantle (*d*.) The muscular fins (*c*,) support, on their pectinated surface, the numerous ramifications of the branchial vessels; so that the motions of these organs promote the aeration of the blood. In the *pneumodermon*, (Fig. 67. B,) the muscular proboscis (*a*,) and the lateral tufts of tentacula (*b*,) terminated each by a sucker, are retractile, the muscular arms (*c*,) are extended from the sides of an anterior division of the trunk, and the branchiæ (*d*,) are placed, as in the *doris*, on the posterior part of the back, but at a distance from the anus, which here opens on the anterior part of the right side, as in the *clio*. The muscular arms are comparatively large in the small testaceous *cleodora*, (Fig. 67. C. *b*,) as they are also in the testaceous *cymbulia*, represented in Fig. 24. The fleshy mantle of the *cleodora* extends laterally to a distance from the sides of the head (*a*,) and the slender pellucid, depressed, tapering shell (*c*,) is also expanded transversely with deeply grooved sides. The fins for progressive motion are more lengthened and straight in their form in the minute testaceous *cuvieria* (Fig. 67. D. *a*,) where there are dentiform masticating buccal organs, as in a cephalopod, and in which the shell (*c*,) is straight, lengthened, conical, and pointed, like a *belemnite*. The muscular organs of these and the other known forms of pteropods, are constructed, like their shells, on the plan of those of the cephalopods, especially of the lower forms of that class.

The organs of motion in the cephalopods, as in the pteropods, are generally in form of muscular fins extending from the sides of the trunk, and unsupported by osseous rays; they move also by means of the muscular feet developed from the fleshy disk surrounding the head. The *nautilus*, like a gasteropod, is fixed by two lateral muscles to the bottom of its shell, its muscular open mantle is thin and delicate, the muscular funnel is open beneath throughout its whole length, and the mouth, surrounded with strong mus-

cles for the calcified jaws, is provided with broad muscular feet, like the expanded feet of an argonaute, and supporting numerous sheathed tentacula. In the *argonauta*, (Fig. 68. A,) there are eight muscular long feet provided with large sessile suckers, as in other octopods. The ventral, or anterior surface of the body is directed towards the concave or spiral side of the shell, as in the *planorbis*, and other mollusca with orbicular shells, and the dorsal part of the animal with the expanded pair of membranous feet (*g*,) are placed next to

FIG. 68.



the convex outer margin of the shell (*a*.) The mantle is spotted externally, as in the naked cephalopods, and is destitute of muscular fins, as seen in Fig. 68. B, which represents the animal removed from the shell. The shell covering a part of the body has been observed by Poli in the ovum, as represented in Fig. 68. C. *a*. The muscular portion of the posterior pair of feet (Fig. 68. B. *g*,) and the gradually diminishing sessile suckers are continued around the margin of the expanded membranous part (Fig. 68. A. *h*,) so that this pair of feet may be employed as organs of prehension, or for creeping at the bottom, or for swimming

and strong, on the long feet of the octopods, as the *argonaute* and the *octopus*, they adhere to external objects by the close application of their thick muscular margins, and by forming a partial vacuum in their centre. By these organs the cephalopods can creep upwards on a vertical surface, even when out of the water. The *octopus*, destitute of any lateral fins, is assisted in swimming by muscular membranes extended between the bases of the feet; this animal swims backwards by impelling the water forwards, but the species which have lateral fins extending from their trunk can swim with ease either forwards or backwards, and they appear to spring upwards sometimes, to a distance from the surface of the sea. These predacious animals have very powerful muscles connected with the mastication of their food, as well as with its prehension. Large sphincter muscles, with a fimbriated fleshy lip, surround the entrance of the mouth, and strong retractor muscles of the jaws are inserted around the œsophageal opening of the cranium. The bases of the jaws are surrounded with superimposed strata of powerful compressor muscles, and the short, thick, fleshy tongue, covered with numerous rows of sharp, conical, horny spines, is moved by strong muscles attached to a rudimentary os hyoides. The maxillary apparatus is also provided with two lateral rotator muscles, which pass forwards to be inserted into its anterior part.

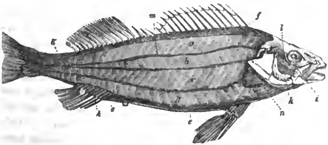
FIFTH SECTION.

Muscular System of the Spini-Cerebrated or Vertebrated Classes.

The muscular system is placed on the exterior of the hard parts in the vertebrated animals; its fibrous structure is here the most distinct and irritable, and its separate muscles and fasciculi are most obvious and defined. The muscles have generally a red colour, from the red blood sent through them, and they are connected with the bones, for the most part, by tendinous prolongations. They are most pale, soft,

and pellucid, in fishes, where their feebleness is compensated for by the great number which co-operate in the same movement. The progression of fishes being effected chiefly by the lateral motions of the tail and of the trunk, the vertebral column is expanded vertically upwards and downwards, and the great muscles of the trunk are disposed in transverse strata along its sides, like those which move the segments of a worm or an insect. The feeble irritability of the muscular fibres in fishes, their softness, and their colourless transparency, correspond with their common conditions in the invertebrata, and in the embryos of the higher vertebrated classes, and they accord with the still soft condition of the bones into which they are inserted. Aided in their ascent and descent in the water by the compression and expansion of their air-sac, and with very imperfectly developed arms and legs, the active movements of fishes are but little varied, their muscles seldom divide into fasciculi, or terminate in narrow tendons to be attached to small points of their feeble skeleton. The fibres which compose the great lateral muscles of the trunk run in a longitudinal direction, are divided into numerous transverse oblique strata by intervening tendinous aponeuroses, and are disposed chiefly in four series of oblique muscles, as seen in the *perch*, (Fig. 70. *a*, *b*, *c*, *d*.) The in-

FIG. 70.



tervening white tendinous bands which connect these strata of muscles have a crescentic form, are disposed vertically along the sides of the vertebræ and the ribs, and are attached externally by their zig-zag margin to the inner surface of the skin. The upper series (*a*,) have their thin white tendons

directed obliquely downwards and backwards, the second (*b*,) downwards and forwards, the third (*c*,) like the first, and the fourth (*d*,) like the second. The upper series of lateral muscles (*a*,) attached anteriorly to the occipital bone, occupy the deep cavity on each side of its projecting spine, and extend backwards to the longitudinal diverging tendons and muscles of the caudal fin, in which they terminate. The oblique direction of all these lateral muscles increases the velocity of their motions, as in the intercostals of quadrupeds. These strata of muscles are arched backwards, having all their convex surfaces directed forwards, and as their fibres pass obliquely backwards and peripherad, they draw their cutaneous attachments forwards and inwards when the vertebræ are the fixed points. They are attached also to the temporal bone and to the back part of the scapular arch, and the inferior series (*d*,) extends forwards under the arms (*n*,) to the os hyoides. The layers of these large lateral muscles of the trunk are seen similarly disposed in the cylindrical body of the cyclostome fishes, in the compressed trunk of most of the osseous forms, and also in the broad depressed body of the flat fishes. They correspond with the vertebræ into which their aponeuroses are inserted, and they are at once analogous to the muscles of the segments of articulata and to the more lengthened and isolated muscles of the vertebral column and trunk in higher vertebrated classes. The flat surfaces of the interspinous bones (*f*,) are covered with diverging muscular fibres, which pass downwards and move them in every direction, and exterior to these are larger distinct muscular fasciculi which are inserted into the broad bases of the rays of the median fins, for their varied movements. The longitudinal straight muscles which extend along the median line of the dorsal and the abdominal surface of the trunk are interrupted by the dorsal and anal fins. The longitudinal straight muscle of the back in fishes generally commences from each side of the spine of the occipital bone, and proceeds in two separate fasciculi to be inserted into the base of the anterior ray of the first dorsal fin. When there are more than one dorsal fin, it is extended in two fasciculi from the last ray of each of these fins to the first ray of the next, and it is continued in the same manner (*g*,) from the last dorsal to the beginning of the caudal fin. On the ven-

tral surface of the body, the first pair of straight muscles generally pass from the scapular arch or the humeri to the anterior part of the pelvis, the second pair (*e*,) commence from the pelvis, and passing on each side of the anus, continue to the first ray of the anal fin (*h*.) They are developed between the anal fins, as between the dorsal, when there are more than one, and from the last ray of the posterior anal fin they are continued backwards to the beginning of the caudal fin. By these longitudinal straight muscles above and below, the median fins are moved and supported, and the trunk is moved in a vertical plane. The sides of the head are occupied by two large and powerful muscles, (*k*, *l*,) apparently analogous to the masseter and the temporal muscles, and which pass forwards and downwards to be inserted into the lower jaw. The lower jaw is depressed both by muscles passing backwards from it to the os hyoides, and by those which extend from the os hyoides to the scapular arch. The operculum is raised by two or more short and broad muscles, placed at its upper part, and is depressed by short round muscles placed on the inner surface of the same part. The branchiostegal rays are moved by short oblique muscles, which descend from the opercular bones to these rays, and by others which are interposed obliquely between each pair of rays, like intercostal muscles in higher classes. The branchial arches, in the osseous fishes, are attached by distinct muscles to the back part of the skull, to the sides of the vertebræ, and also to the scapular arch and the os hyoides. In the cartilaginous fishes, where there is no operculum over the branchiæ, that apparatus is covered externally with a layer of short muscles, like intercostals, passing between soft cartilaginous bands, like ribs. The pectoral fins, or arms, have on each of their flat surfaces a band of adductor and abductor muscles, (Fig. 71. *f*,) which extend from the scapular arch to the commencement of the phalanges or rays. These muscles act also as flexors and extensors of the arms, and correspond with the magnitude of these organs; they are greatest in the expanded pectoral fins of the plagiostome fishes. The ventral fins or feet are also moved by two similar muscles (Fig. 71. *h*,) on each of their flat surfaces, extending from the pelvic bones to the commencement of the rays, and corresponding in size and strength with the magnitude of the feet. The anguilliform

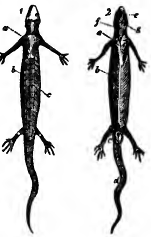
FIG. 71.

fishes want the feet and their muscular apparatus, and the cyclostome fishes want also the arms and their muscles. The muscular system is greatly relieved in the vertical motions of most fishes by the compression and expansion of their air-sac; but many of the flat fishes and the cyclostome species are destitute of this aid, and lie generally at the bottom of the water. The movement of some fishes through the water is aided by a muscular disk in form of a sucker, placed on the back part of the head in the remora, on the fore part of the belly in the lump-sucker, and around the mouth in the lampreys, by which they adhere to other animals or bodies moving through the water. By the great development of the lateral muscles of the trunk, the saw-fish and the sword-fish are enabled to use their offensive weapons with effect; the large muscles of the anterior dorsal rays give powerful and varied movements to these parts in the silurus, balistes, lophius, and many other fishes, and the strength of those of the pectoral fins enable the flying-fishes to escape from the water, and to move some hundred times their own length through the air.

The long compressed trunks of the perenni-branchiate amphibia, as the *proteus*, the *siren*, and the *axolotl*, and of the tadpoles of the higher anurous species, are moved through the water chiefly by the lateral motions of the vertebral column and of the tail, as in fishes, and these motions are effected in the same manner by numerous transverse strata of longitudinal muscular fibres, occupying chiefly the sides of the trunk. These great lateral muscles are still comparatively pale, bloodless, and feeble, and the tendinous intersections of their strata are thin, soft, and delicate. The cellular substance interposed between the muscles of amphibia is scanty, of little consistence, colourless, and almost in a semifluid state; there are yet few tendons connecting the muscles to the soft bones of the skeleton, and there is gene-

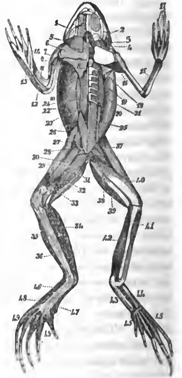
rally very little connexion between the skin and the subjacent muscles of the body. The general disposition of the superficial muscles in the urodelous amphibia is seen on removing the skin from the common crested triton, *triton cristatus* (Fig. 72.) In the back view of the trunk (Fig. 72. 1,) short transverse strata of lateral muscles (*b*,) separated from each other by thin, soft, tendinous aponeuroses, are seen occupying the dorsal portion of the body, from the occipital bone to the posterior extremity of the tail. The muscular strata (*c*,) which descend from these in a more oblique direction downwards and backwards, are united together on the fore part of the abdomen (Fig. 72. 2. *b*,) to form a large continuous descending oblique muscle. But behind the anus (2. *c*,) the tendinous intersections (2. *d*,) continue distinct along the tail, below the vertebral column as well as above it. In the rigid state of these lateral muscles in the tadpoles, as in that of the *rana paradoxa*, the sides of the trunk are marked by transverse vertical furrows, similar to those on the sides of fishes. We perceive also in the tadpoles, as in fishes, a thin vertical prolongation of the skin along the upper and lower surfaces of the tail, like dorsal and anal fins, but unsupported by rays. The *recti abdominis* of the tadpoles form a broad muscular expansion covering the fore part of the trunk, divided by several transverse tendinous intersections, and tapering to the pelvis. These two muscles become more contracted and narrow in the adult animal. In the salamander strong muscular fasciculi descend from the free ends of the short ribs of the trunk, and expanding as they pass over the abdomen, they unite to form a continuous external oblique. The muscles of the extremities are more developed in these animals, to support them on land, than in the tritons and other aquatic species, where they are little used for progressive motion. In the anurous species, in their adult

FIG. 72.



state, the muscular system is the most remote from that of fishes in its general characters and in the disposition of its parts, which arises from their greater extent of respiration, their inhabiting a rarer medium, the great development of their extremities, and the large portion of the trunk which they lose by their metamorphosis. Their muscles are more vascular, dense, red-coloured and strong, more distinct and defined in their course and in their insertions, more ventricose, seldom exhibiting parallel strata, and generally inserted into distinct and often lengthened tendons. From the leaping and swimming habits of many of these species, we perceive their short trunk terminated by lengthened and strong legs and provided generally with less perfectly developed arms, and the greater development of the extensors than of the flexors of the legs, gives an anthropoid character to these extremities. In the back view of the muscular system of the common frog, *rana esculenta* (Fig. 73,) the small size of *levatores scapulæ*, (1. 2,) corresponds with the soft and feeble condition of the dorsal portion of these bones into which they are inserted. The depressor of the lower jaw (5,) the scapular (6,) and the sub-scapular muscles (8,) occupy the anterior part of the back immediately behind the head, having before them the broad temporal muscles, and behind them the *quadratus lumborum*, (19, 24,) the *sacro lumbalis*, (23,) and the dorsal portion of the *obliquus externus* (22.) The *ilio-coccygeus*, (25, 26,) is of great length, like the coccygeal bone, and the ilium to which it is attached, and the *trans-*

FIG. 73.

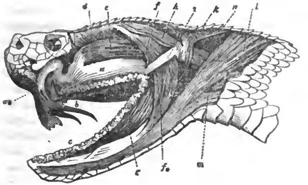


versus abdominis (20,) extends over a large portion of the trunk from the want of ribs in these anurous amphibia. The *inter-transversales* (21,) are of considerable breadth, from the length of the transverse processes of the vertebræ. The *pectoralis major*, here of great size and strength, is divided into several distinct parts, which extend forwards, inwards, and backwards, as separate flat muscular bands, covering a great portion of the anterior surface of the trunk. The muscles of the os hyoides are of great size, as in fishes and the lower amphibia, from the size of that bone, and its importance in respiration where there are no ribs. The *pectoralis minor* is also divided into several detached and diverging muscular bands, like the external, and both these muscles acquire increased influence on the arm by their low insertion on the short humerus. The deltoid (7,) the anconei (9, 10,) and most of the proximal muscles of the arm are strong ventricose masses, and even the flexors and extensors of the wrist and fingers are short and fleshy, giving an anthropoid character to these members. The knees extend, not forwards as in most vertebrata, but directly outwards from the sides of the trunk, and the long webbed feet have the same lateral direction, the best adapted for swimming and leaping. The *glutei* muscles (27,) are here long and narrow, from the lengthened and cylindrical form of the iliac bones, and also the *iliaci* muscles (28, 37,) and the *semi-tendinosus* (33,) the *semi-membranosus* (31,) and other extensors of the thigh. The *recti* (29,) and the *vasti* muscles (40,) and the other extensors of the knee-joint, and also the *gastrocnemius* (34,) the *tibialis posticus* (42,) the *peronei* (48,) and other extensor muscles of the heel are here of great size, and of great importance in the progressive motions of these animals both on land and in the water, and by their great development they give a rotundity to the thighs and to the calfs, unusual in the cold-blooded vertebrata. The plantar aponeurosis is here continued from the *tendo achilles*, which has a moveable sesamoid bone where it plays over the heel; so that the great extensors of the heel-joint contribute likewise to the flexion of the toes, and the general support of the long webbed feet in swimming through the water, or in leaping on the ground.

The higher classes of air-breathing vertebrata, by respiring

a purer element and by possessing organs more extensive, and more complicated, for the aeration of their blood, have their muscular system encreased in energy and strength beyond that of the fishes and amphibia, which, for the most part, are organized to move by means of their vertebral column, through an element nearly of the same specific gravity as themselves. The rarity of the medium through which most of the reptiles and higher animals move, necessitates this increased muscular strength, and their bones have an increased solidity proportioned to the greater force of the muscles which are to act upon them. The progressive motion of serpents, like that of fishes, depends upon the movements of their trunk, and their muscles are disposed so as to act with most effect on the sides of the vertebræ and on the ribs. The deep grooves along the back, between the spinous and the transverse processes on each side, are occupied chiefly with the *multifidus spinæ*, the *spinales*, and the *semi-spinales dorsi*, which inflect powerfully the column to either side. Short as the distance is from one spinous process to another, and between the short transverse processes which support the ribs, those parts are moved separately by strong *interspinales* and *intertransversales* muscles. The ribs being free at their distal extremities, they admit of extensive motion, and are furnished with large intercostal muscles which partly represent the oblique and transverse muscles of the abdomen in higher animals. The *recti* muscles are divided in front by the soft cartilaginous tapering extremities of the ribs, as they are by tendinous intersections in most of the higher animals. These intercostal muscles, of various lengths, some passing directly from one rib to the next, and others passing over one or more ribs, to have a more distant insertion, are strongest on the anterior portion of the trunk, where their action is important in respiration, by compressing and expanding the respiratory sacs. The large imbricated abdominal scuta, so important in the progression of serpents, are moved and supported by distinct muscular fibres, which pass down to their fixed extremities. Many of the ordinary muscles of the head, as seen in that of the *rattle-snake* (Fig. 74,) have a lengthened and divided form in serpents, from the elongated form and the great mobility of most of the bones of that part. An-

FIG. 74.



terior to the *external pterygoid* (*k*,) and the *digastric* (*h*,) muscles are seen three separate parts of the *temporal* muscle (*d, e, f*.) A portion of this muscle (*e*,) extending forwards like a *buccinator*, embraces the posterior part of the poison-gland (*a*,) and forces the secretion into the duct (*a**,) and thence into the perforated fang (*b*.) The strong muscles of the lower jaw (*l, m*,) extend upwards to the vertebræ and backwards to the ribs, and unite into a single band on their fore part. The row of salivary glands (*b, c*,) extend backwards beneath the poison gland (*a*,) and forwards before the *masseter* muscle (*g*.) The great length of all the muscles of the head and trunk of serpents contributes to the velocity of their movements, and their numerous subdivisions contribute to the variety of their motions. Their muscles, for the most part, terminate in narrow, shining, tendinous bands, which allows of a greater number of muscles being inserted into a limited space, and consequently a greater variety in the movements of the articulations. These elongated forms, and tendinous terminations are most conspicuous in the external and internal muscles of the ribs, which are the legs of these animals. The cloaca has its distinct muscles for opening and closing that cavity ; the pelvic bones and rudimentary feet, sometimes developed, are provided with muscles analogous to those of the ventral fins and pelvic bones of fishes ; the scapular arch, developed in the most per-

fect species, is attached by muscles to the trunk, though not yet destined to support atlantal extremities, and the internal lateral muscles passing from the vertebræ to the ribs, form the rudiment of a diaphragm.

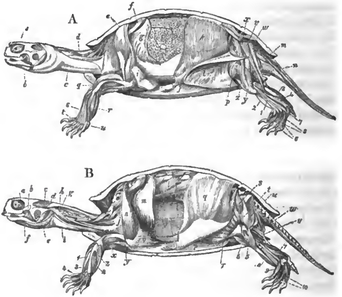
The muscles of saurian reptiles are more numerous and complicated than in ophidia, because they possess members for progressive motion, adapted sometimes for swimming and sometimes for running or climbing, and sometimes these animals are organized for moving through the air. The stratified disposition of the great lateral muscles of the trunk, so conspicuous in the fishes, the urodelous amphibia, and even in the serpents, is less marked in the comparatively motionless bodies of the saurian reptiles, excepting in those which have scarcely yet the members developed. This arrangement of the muscles, in regular series around the vertebræ, is still continued in the coccygeal region of the column, which, together with the neck, is more flexible than in the ophidia. Several muscles of the face are wanting on the rough and hard head of the crocodilian reptiles, their temporal and masseter muscles are protected externally by the temporal, frontal, and malar bones, and their insertions are on the inner surface of the lower jaw, the muscles of the os hyoides, and those which connect the head with the trunk are distinct and powerful, as in most reptiles, and those of the tail, which is nearly as thick as the trunk, are of great strength, for the lateral motions of that part in swimming. The short muscular legs of these animals, diverging outwards, scarcely raise the trunk off the ground, on which the saurians, and most other reptiles rest the body, when not in actual progression. The legs, in these aquatic sauria, are compressed in form, to facilitate their advancement in the water, as in web-footed birds, and they have strong extensor muscles, to give impulse to their webbed feet. More nimble movements, andmore lightand pliant forms of the locomotive organs and of the whole body are seen in most of the terrestrial, climbing, long-toed,and long-tailed lacertine sauria. The direction outwards of the humerus and femur weakens the limbs, and adapts them better for climbing and prehension than for support or for running. The long fingers and toes, with their powerful flexors in the lacertine sauria, adapt them for climbing on trees in pursuit of their prey. The opposed

fingers and toes, and the muscular prehensile tail of the chamœlion enable it to creep with security on the agitated branches ; the muscles of its eyes are not synchronous in their movements, by which it commands an extensive field of vision without moving its head, and the muscular, clavate, prehensile tongue is moved with velocity, like a sheath to and fro, from the long body of the os hyoides. The powerful intercostals of the flying dragon expand its ribs with their connecting skin, and move them like wings, to enable it to pursue its insect prey through the air. The saurian reptiles, possessing a more distinct cervical region than any of the inferior vertebrata, and often carrying bulky prey to a distance in their jaws, require a great development of the muscles which suspend and move their heavy head and neck, as the *recti* and *obliqui* muscles of the head, the *splenii*, *scaleni*, *complexus* and *serratus posticus*, the *inter-* and *semi-spinales colli*, the *transversalis*, *trapezius*, and *rhomboideus*. The fibres of the *panniculus carnosus* are intimately connected with the large osseous, external plates of the loricated crocodilian reptiles, but the skin is more free in the lacertine species. The external and internal *obliqui abdominis* and the *transversalis* are distinct in the crocodiles, and also a rudiment of the diaphragm. The posterior portion of the diaphragm is likewise perceived in the *dragons* and *geckos*, where it consists of muscular bands ascending from the bodies of the vertebræ to be attached to the ribs before them.

Many of the ordinary muscles of the trunk are wanting in the chelonian reptiles, from the immobility of the skeleton in that part of the body, especially in the land species. Several muscles of the face are deficient from the immoveable horny covering of the jaws and lips, and from the close application of the horny scales to the periosteum in that part. The muscles on the dorsal part of the spine, and all the intercostals, are likewise deficient. Those of the cervical, sacral, and coccygeal regions, and those of the scapular and pelvic arches, together with the muscles of the arms and legs, are the most distinct and powerful in this order, and correspond with the mobility of these parts, or the weight they have to sustain. The *temporal muscles* are covered over by the parietal bones in the turtles, but in the tortoises,

where the whole head is easily withdrawn within the strong arched and capaceous carapace, these muscles are exposed on the sides of the cranium (Fig. 75. A.) as in warm-blooded animals. The *orbicularis palpebrarum*, (Fig. 75. A, *a*,) is

FIG. 75.



here thin and feeble, and chiefly appropriated to the large moveable lower eye-lid. The *oblique muscles* of the eye-ball are also very small, while the *recti* and the *suspensorius oculi*, (Fig. 75. B. *a*) are more distinct and strong. The mylo-hyoideus (Fig. 75. A. *b*,) and the *latissimus colli* (75. A. *c*,) here form a large panniculus carnosus, covering the whole of the lower part of the sides of the neck. The *spinalis cervicis*, (A. *d*,) here forms numerous strong detached bands, which principally support the head, and retract it, when alarmed, within the cavity of the trunk. Behind this muscle lies the insertion of the *longus colli*, (A. *f*,) which has a similar action on the neck. Between these extends downwards the *latissimus dorsi*, (A. *e*,) tapering to the humerus, before which is the extended *latissimus colli*, and the imperfect diaphragm, (A. *g*,) extending over the peritoneal covering of the lungs. The

obliqui, (A. *l*,) and the *transversales abdominis*, (A. *k*,) are here of considerable extent, passing forwards around the abdominal cavity, beneath the sternum and the ribs, and assisting in respiration and in the discharge of all the natural excretions. Behind the diaphragmatic bands (B. *l*, *m*,) are the posterior insertions of the large *retrahentes capitis et colli* (B. *k*,) which extend forwards along the back part of the neck (B. *j*,) to retract the head and neck under the ribs. As the ribs are immoveable, the motions of inspiration are effected chiefly by the *os hyoides*, as in amphibia where the ribs are almost or completely wanting, and most of the muscles connected with that bone are large and distinct, like the parts of the os hyoides itself. The *genio-hyoideus* (B. *f*.) forms a broad muscle extending forwards to the lower jaw, and the *omo-hyoideus*, (B. *i*,) continues backwards as a broad muscular expansion, covering the lower part of the neck. The *hyo-glossus*, *hyo-maxillaris*, *genio-glossus*, are also here distinct, and the *sterno-mastoideus*, the *digrasticus maxillæ*, *trachelo-mastoideus*, (B. *h*,) and most of the muscles which move the head, are well marked in these long-necked animals. The large pectoral muscles have an extensive attachment to the interior of the sternum. Two broad muscles proceeding, in different directions, from the sternum to the pubic bones, and constituting the *attrahens* and *retrahens pelvim* on each side, appear to be the analogues of the *recti abdominis*. The *serratus magnus*, *deltoides*, *sub-* and *super-scapularis*, *triceps*, (A. *q*,) and *biceps* (B. *y*,) *brachii*, and most of the succeeding muscles of the arm and hand are powerful, especially in the land tortoises, where the arms are fixed in a state of pronation, the best suited to support the weight of the body. The *flexor sublimis* (A. *r*,) forms a strong muscular band on the outside of the fore-arm. The broad tendons of the *extensor communis digitorum manus*, (A. *s*,) cover the back part of the carpus, and on the upper part of the fingers are the five strong *extensores breves digitorum manus*, (A. *t*.) The *brachialis internus* (B. *x*,) the *palmaris*, (B. *z*.) the *flexor profundus*, (B. 2,) and most of the flexor muscles of these extremities are strong, both for support and for digging. In the long, fin-like arms of the turtles, the muscles of the shoulders are those chiefly developed, while the muscles of the fore-arm and hand are very feeble, as in ceta-

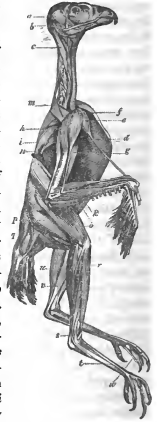
ceous animals. The *glutei* (A. *o*,) *the iliacus internus*, (A.*p*,) and the *psoas*, are strong muscles in the land species, as are almost all the extensors and flexors of the thigh-bone. The *biceps cruris*, (A.*v*,) and the *semitendinosus*, (A. *w*,) form long muscular bands behind the femur, and the *rectus femoris*, (A. *x*,) in front, which unites below with the *vastus externus*, (A. *y*,) the *vastus internus*, and the *crureus*, to be inserted into the tuberosity of the tibia, below the knee, by a common tendon. The *sartorius* (A. *z*,) *semimembranosus*, *obturator*, and *gracilis*, have bere their usual position and action. The *extensor communis digitorum pedis*, (A. 1,) and the *short extensors* of the four toes, (A. 5,) resemble the corresponding muscles of the hand. The *peroneus*, (A. 4,) the *gastrocnemii* (A. 3,) and the othèr extensors, are strong on the posterior as those on the anterior extremities in the tortoises, to support and move their heavy body on the land, but they are scarcely perceptible in the long flat fin-like feet of the turtles. The cloaca has its dilating and its sphincter muscles, and the highly moveable tail bas its numerous flexors and its extensor muscles in the reptiles of this order, and even the glottis, the penis, and the clitoris, have already their accompanying muscles developed, as in higher animals.

The muscles of *birds* are more red and vascular, more irritable and dense than in the cold-blooded vertebrata beneath them, and they possess these properties in the greatest degree in the rapaceous tribes, where the respiration is greatest, and where all the functions are most energetic. This condition of the muscular system is required in birds, from the lightness of the medium through which they move, and from their quick and long continued movements through that element. The muscles are more feeble, pale, soft, and palatable in the heavy, slow-moving, phytophagous tribes, where the condition of the bones and most of the other systems, mark an inferior or reptile state of development. The fleshy parts of the muscles are generally short and thick, especially in the arms and legs of birds, and their tendons are generally long, slender, dense, and often ossified, like many cartilaginous parts of the skeleton. The active, heavy, fleshy parts of the muscles being situate, for the most part, on or near the solid trunk of the bird, the extreme parts, so important for progression, are lightened by receiving and supporting

only the long narrow tendons; hence the long slender legs and the lightness of the arms in this class. As birds have nearly all the same general form and movements, there is remarkable uniformity in the muscular system throughout this class. Their trunk being almost as fixed as in the chelonia, the muscles destined to move that part are here also very imperfectly developed, but its fixed condition affords the most advantageous attachment for the powerful muscles of the extremities, which have generally a very high origin. The arms and hands being entirely appropriated to flight, and the legs and feet being constructed chiefly for support, their long flexible neck and highly moveable head supply the place of anterior extremities for all ordinary purposes of prehension, and the cervical region is therefore strong, moveable, and muscular, like the trunk of a serpent. The face of the birds, from the immoveable horny sheaths which cover the exterior of the jaws, is like that of the crocodilian and chelonian reptiles, destitute of many muscles destined to move the fleshy lips in other classes. The *temporal*, (Fig. 76. *a*,) the *masseter*, and the *pterygoid* muscles are powerful in birds, and correspond with the great length and the mobility of their lower jaw; they are stronger in the rapacious birds, from the resistance they have to overcome, and they are most unequally developed on the two sides of the head in the *crossbills*, which habitually draw the lower jaw to one side of the head. The large eyes in this class are moved by four *recti* muscles, as in mammalia, and have their middle portion surrounded, compressed, and rotated by two *obliqui*. The *orbicularis palpebrarum*, expanded over their large orbit, acts most on the lower eye-lid, as in inferior classes; the lower eye-lid has also its small *depressor*, as the upper has its *levator* muscle, and the *membrana nictitaus*, with its long inferior tendon passing behind and over the ball, is moved with great velocity by its *pyramidalis* and *quadratus* muscles. The fixed condition of the dorsal vertebræ affords a more solid attachment to the muscles of the long neck, and in rapaceous birds, which frequently carry their prey suspended from their jaws, to a distance through the air, the neck is comparatively short and strong, and the muscles of great power which move these vertebræ, as seen in the annexed figure from Carus, representing the muscles of the *falco*

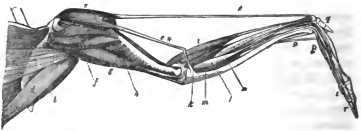
nisus, (Fig. 76.) The *recti postici* and *antici*, the *obliqui capitis*, the *splenii capitis et colli*, and the strong *complexi* (Fig. 76. *c*,) rotate the head on its single occipital condyle, and bend the neck to either side. The *inter-transversales*, *interspinales*, *transversalis colli*, *spinales dorsi et colli*, *trapezius*, *cucullaris*, *biventur cervicis*, *rhomboideus*, *trachelo-mastoideus*, and *scaleni* muscles are also well marked in the flexible neck of birds, and important in the movements of this part of the skeleton. The *longus colli* passes upwards from the spinous processes of the lower cervical and anterior dorsal vertebræ, to be inserted into the transverse processes of most of the vertebræ of the neck. The *external intercostals* are divided each into an anterior and a posterior, half by the osseous appendices extending backwards from the margins of the ribs, and the *internal intercostals* extend backwards no farther than these appendices. The *serrati*, the *latissimus dorsi*, the *obliquus externus*, and *internus abdominis*, the *transversalis* and most of the muscles confined to the trunk are feeble in this class. The broad thin *recti abdominis*, connected together by a broad *linea alba*, and destitute of tendinous intersections, diverge at their posterior or lower part, to be inserted into the detached and feeble pubic bones. The muscular parietes of the abdomen are here thin and feeble, and very short, from the greater portion of that cavity being covered and supported by the large sternum, and the muscular bands forming the rudimentary diaphragm extend upwards and inwards from the margins of the sternal

FIG. 76.



ribs, spreading like a thin aponeurosis over the peritoneum covering the abdominal surface of the lungs, as in many of the cold-blooded vertebrata. The *iliacus* is here a small muscle within the pelvis, and the *psoas* appears to be wanting, but the *glutei* muscles are of great strength, having to support the whole weight of the trunk upon the posterior extremities alone, as in the human body. The tail is moved, and its feathers are expanded, by several lateral muscles both above and below the coccygeal vertebræ, extending from the sacrum to the spinous, and to the transverse processes, and extending to the bases of the large quill-feathers themselves. The anterior extremities, like the posterior, have the proximate muscles of great magnitude and strength, while the more distant muscles of these parts are comparatively small and feeble, and those are especially strong which are placed on the fore part of the sternum, and effect the depression of the humerus, the most powerful and important movement in the flight of birds. The *pectoralis major*, (Fig. 76. *d*,) covers nearly the whole surface of the sternum and its crest, and continues its origin along the edge of the clavicle, and the surface of the broad ligament which unites the clavicle to the upper margin of the sternum. The insertion of this muscle is extended along a great portion of the humerus, and its magnitude corresponds most generally with the power of flight, and the rapaceous character of the species. The *subclavius*, the *serrati*, the *subscapularis*, and most of the muscles connected with the scapula, on the upper part of the shoulder, are small in birds as in reptiles, and correspond with the limited extent of surface of that bone. Beneath the extended *pectoralis major* are the long narrow *pectoralis minor*, and the *coraco-brachialis*, which, from its position, looks like a third pectoral muscle. The integuments on the fore part of the wing are expanded like a web, in the bent position of the arms, by two long elastic tendons which originate from a strong cutaneous muscle like a deltoid, extending from the scapula over the head of the humerus, (Fig. 76. *d*, *e*.) One of these tendons is short, and extends only to a small distance beyond the lower end of the humerus, while the other extends to the wrist, as seen in the annexed figure of the wing of the common buzzard, *falco buteo*, (Fig. 77. *e*,*e*,*e*.*) In this back view of the muscles of the arm in a

FIG. 77.



rapaceous bird, the small thin *cucullaris*, (*a*, *a*,) is seen extending outwards from the vertebral column, and above it the two divisions of the *latitsimus dorsi*, (*c*, *d*,) which cover also the *infra spinatus*, (*b*.) The short fleshy mass of the *deltoid* muscle (*f*,) extends to the middle of the humerus, and behind it is the long *triceps extensor cubiti* (*g*, *h*.) On the fore-arm are seen the fleshy parts of the *extensor carpi radialis* (*i*,) with its long tendon passing over the end of the radius, the *supinator radii brevis* (*k*,) the strong *extensor digitorum communis* (*l*,) and beneath this the *extensor metacarpi ulnaris* (*m*, *n*,) which has its long tendon inserted into the middle strong element of the single metacarpal bone in birds. Beneath the thumb (*q*,) is the very small *flexor pollicis*, and on the ulnar side of the long middle finger (*r*,) is the tendon of the *abductor indicis* which passes down fleshy between the long anchylosed metacarpal bone, and has its tendon inserted into the base of the last phalanx. The *flexor indicis* has its tendon inserted into the distal extremity of that phalanx (*r*.) The *flexor carpi ulnaris* (*p*,) passes fleshy along the ulnar side of the outer metacarpal bone, and the outer finger, consisting of a single minute phalanx, has its own *flexor digiti minimi* (*s*.) The muscles and articulations of the wing are chiefly adapted for adduction and abduction, and they admit of little flexion and extension, or promotion and supination, excepting at the head of the humerus; so that the whole arm moves with greater solidity and effect as an organ of flight, and is more easily folded along the side of the trunk when in a state of repose. On the posterior extremities the extensor muscles are more developed than the flexors from

the trunk being supported by these members alone in walking. From the extent, and the fixed condition of the dorsal part of the pelvis, the extensors of the femur have a high origin and a lengthened form, and the *gluteus maximus*, *medius*, and *minimus* are developed in this region, as in quadrupeds. The *gluteus maximus* here reaches along the femur, as low as the fibula, passing below and behind the knee-joint. The only distinct abductor of the femur is the *gemellus superior*, which rotates the thigh outwards, and this muscle is deficient in many aquatic birds. The *pyriformis*, *quadratus femoris*, and *obturator externus* extend the femur, and are aided by a muscle analogous to the *pectineus*. The *peroneus longus* and the *tibialis posticus*, arising from the back part of pelvis, are connected below with the extensor tendon of the heel. The *rectus femoris* arising from the upper part of the pubis, continues its long tendon over the extensor tendon of the knee, and unites below with the common perforated flexor of the toes. The *gracilis* arises very low from the femur, and acts as an extensor of the knee, and the *popliteus*, directed transversely, is situated high on the tibia. The foot is raised by the *tibialis anticus*, which passes from the tibia to the metatarsal bone, and rotates the foot inwards in the climbing movements of the zygodactylous birds ; these birds have likewise the *peroneus brevis* of considerable size, which arises from the exterior of the tibia and fibula, and rotates the foot outwards. The *gastrocnemius*, (Fig. 76. *u*,) arises from the condyles of the femur, and passes down thick and fleshy to the broad aponeurotic tendon of the heel, which forms a groove for the passage of the flexor tendon of the toes, and is inserted below into the long metatarsal bone. Behind the *tibialis anticus* (Fig. 76. *r*,) arises the fleshy head of the *extensor longus digitorum*, (Fig. 76. *t*,) the tendon of which, bound down by strong ligaments in its course, divides at the lower end of the metatarsal bone, into three separate tendons, which proceed along the upper part of the toes to be inserted into the base of each terminal phalanx. The posterior toe has a distinct extensor muscle which descends from the upper part of the metatarsal bone, and is inserted into both phalanges. The *long flexor of the toes* descending from the upper part of tibia exterior to the *gastrocnemius*, is connected with two cartilages at the heel-joint, which represent

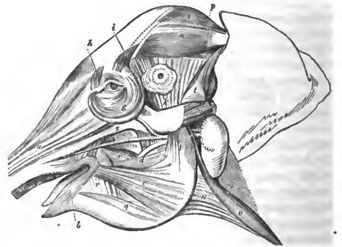
the astragalus and the calcaneum, and which I have found in the ostrich, in the condition of a large, solid, sesamoid bone.

The muscular system of the *mammalia* is greatly diversified by the variety of forms and habits of the animals which compose this class, some of which are organized to move like fishes through the ocean, some to burrow in the earth or to walk on its surface, or to climb on trees, and others to fly like birds through the air. The differences here presented by the muscular system relate therefore chiefly to the organs of motion, which vary according to the nature and situation of the food. The fleshy parts of the muscles in mammalia are generally large and strong, and proportioned to the more massive bones of the skeleton, and the encreased weight of the whole trunk. The respiration being less extensive here than in birds, the temperature is inferior, the tendons are less inclined to ossify, the circulation is slower, the muscular fibres are less dense, and their contractions are less energetic, and the muscles compensate for their defective energy by their increase of bulk, which gives a rotundity to the exterior form of the body, and more massive proportions to all the parts of these animals. As the cetaceous animals breathe by lungs, and not by gills, like fishes, the muscles of their vertebral column are disposed chiefly for movements in a vertical plane, and not for horizontal motions, like those of the water-breathing fishes. The great elevation and breadth of the occipital region of the cranium afford an extensive surface of attachment, as in fishes, for the powerful muscles of their short fixed neck, and extended moveable trunk. From the great length of the transverse and spinous processes of nearly all the vertebræ of the trunk, there is a large angular space on each side of the column, for the numerous long and powerful muscles which move the caudal vertebræ, and the tail, and the fleshy bodies of these muscles are very indistinctly separated from each other, from the general similarity of their direction and uses. The *splenii* muscles of the head and neck, the *longissimus dorsi*, the *sacro-lumbalis*, the *trachelo-mastoideus*, the *spinalis dorsi*, and the *complexus*, are here especially distinct on the dorsal region of the column, and important in its backward movements. On the lower part of the column is the large *quadratus lumborum*, and two

muscles analogous to the *psoas* and the *iliacus*, which powerfully assist in the downward movements of the coccygeal vertebræ. The *oblique*, the *transverse*, and the *recti* muscles of the abdomen are lengthened and feeble on the long trunk of the cetacea, and the abdominal ring is wanting, as in other mammalia, where the testes remain permanently in the abdominal cavity. The proximate muscles of the anterior extremities, the *subscapular*, the *infra-spinati*, the *pectoral* and the *deltoid* muscles, are those principally employed in the movements of these fin-like organs. The more distant muscles of these extremities, however, especially the flexors of the fore-arm and hand, are much more developed in the herbivorous cetacea, which are able to seize and to climb upon rocks. The muscles of the *pharynx*, of the *os hyoides*, and of the exterior nares, are numerous and distinct in these animals, and correspond with the magnitude and the mobility of these parts. The compressor muscles, embracing the expanded nostrils of many of the blowing cetacea, enable them forcibly to expel columns of water taken in by the mouth, and the extension of these muscular cavities allows them to breathe freely while the rest of their body is beneath the surface of the water. The cetacea, like fishes, amphibia, and serpents, consisting almost solely of the trunk, are moved and supported by its muscles in the dense element they inhabit; but the land quadrupeds require strong members and strong muscular apparatus to support and move their heavy trunk in the light and unresisting element they breathe. In the herbivorous quadrupeds, the muscular energy and development are generally less than in the carnivorous species, which corresponds with the inferior development of their respiratory and nervous systems, and the diminished activity of all their functions. The ruminantia, like the pachyderma, having no clavicles, the humeri are approximated under the thorax, and the anterior part of the trunk is suspended between the long vertical scapulæ by the strong *serrati* muscles, as by a band passing across beneath the chest. From the weight and the horizontal position of the trunk, the extensor muscles of the extremities are more developed than the flexors, and to render these extremities more light and nimble, the distal bones and tendons are lengthened, and the heavy fleshy parts of the muscles, as in

birds, have a high origin. The number, the divisions, and the tendons of these muscles, are fewer than in the more muscular and powerful carnivorous quadrupeds, from the reduced number of the toes. From the weight of the horns, and the use made of these defensive organs in many of the larger ruminantia, as the buffalo, the bull, the gnu, and the bison, the neck is short, and the muscles which support and move the heavy head are large and powerful, and the same is observed in many of the larger pachyderma, from the weight of the teeth, or tusks, or proboscis, or horns. From the great size and mobility of the exterior concha of the ear, in most of the herbivorous quadrupeds, they present a great development of the *attollens aurem*, and of the *anterior* and *posterior auris*, and from the lengthened form of their face and jaws, all the muscles of their lips and nostrils are generally lengthened and strong. The muscles of the nose are particularly strong in the hog-tribe, to enable them to dig up their food with that organ of smell, as they are also in the long flexible nostrils of the tapirs. In the face of the elephant,

FIG. 78.



(Fig. 78,) so remarkable for the extent and flexibility of the nostrils, and for their sensibility and prehensile power, the *levator* and *zygomatic* muscles (*a*, *s*,) of the upper lip are in-

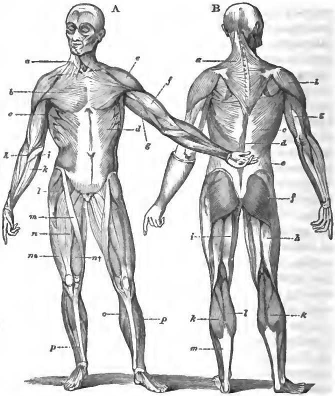
corporated with those of the prolonged nostrils. These *levator* muscles of the heavy proboscis have a strong tendinous attachment laterally (*s*,) to the zygomatic bone, and the anterior fasciculi (*a*,) are attached to the malar, the nasal and the frontal bones. The upper portion of the *orbicularis oris* (*b*,) is extended on each side along the base of the proboscis. Below the levator muscles (*s*,) are seen the large branches of the trifacial nerve proceeding forwards to the muscles of the face and proboscis. Extending downwards and backwards from the angle of the mouth, are several terminal fasciculi of the *platisma myoides* or panniculus carnosus (*c*, *d*, *q*,) and behind the ramus of the jaw is the large parotid gland, with its duct passing forwards beneath the facial nerve. Above the parotid is the *attrahens aurem* (*o*,) passing forwards to the malar bone, and behind the outer margin of the expanded *orbicularis palpebrarum* (*g*,) is the opening of the short duct from the temporal gland. Beneath this gland descends the powerful *temporal muscle* (*k*,) above which are the detached portions of the large *attollens aurem*, (*m*, *n*,) destined to move in different directions the great expanded concha of this animal. Detached muscular fasciculi (*h*, *i*,) descend from the frontal to raise the skin in the region of the eye-brows. The *depressor labii inferioris* (*r*,) is seen extending downwards from the margin of the lip, and the *levator anguli oris* rising obliquely upwards and outwards from the angle of the mouth. The *panniculus carnosus*, which is scarcely perceptible over the trunk in the larger thick-skinned pachyderma, is a strong, fleshy, subcutaneous layer in the softer skinned ruminantia, where it extends from the trunk over the neck to the head, and is attached both to the humerus and to the femur. In the mammalia, covered with spines, as the echidna, hedge-hog, porcupine, and in those covered with imbricated scales, as the manis and the armadillo, this muscle is also important in erecting or moving these epidermic organs, and in coiling or uncoiling the body. The neck is generally short, thick, and muscular in these anteaters, or loricated insectivorous quadrupeds, to assist in excavating the ground with their head in quest of food. In the rodentia, as in birds, the pterygoid and the temporal muscles are strong, and the pteryoid processes of the sphenoid bone have a corresponding magnitude; their *masseter* muscle is also of great

breadth, and by sending its fibres both forwards and backwards from the depressed zygomatic arch, it assists in the longitudinal movement of the lower jaw in both these directions. The whiteness, or pale colour, and the velocity of movement of the muscles of rodent quadrupeds, present further affinities to the class of birds, especially to the heavy inactive vegetable-eating gallinaceous kinds, where the blood is less rapidly and less extensively distributed through their muscular system than in the more powerful rapaceous tribes. The flexor muscles of the arms are generally much developed and much exerted in this order of quadrupeds, either for scraping the ground for food, or for burrowing in the earth, or for climbing upon trees and cliffs. In the marsupial quadrupeds, the abdominal pouch is embraced externally by the *panniculus carnosus*, the fibres of which serve, by their extension over the pouch to the symphisis pubis, to contract that cavity so as closely to embrace the newly-received young, and to protect them during the first period of their extra-uterine life. Within this pouch are the mammary glands, which are embraced by distinct muscular fasciculi destined to compress them and to aid the escape of their secretion, and other delicate fasciculi force the milk from the ducts and the nipples into the mouth of these abortive fœtuses, and thus to extend the nipples from their ordinary retracted condition. The muscular system of carnivorous quadrupeds corresponds, in its high development with the solid texture of their bones, and the great extent of their respiration, the nutritious character of their food, and the living habits and wants of the species. By the magnitude and the extension forwards of the zygomatic arch their large temporal and masseter muscles have an advanced insertion on the lower jaw, most favourable to their action, which is aided by the short truncated or rounded form of the head, especially in the feline animals. The *levator* muscles of the lips and nose serve, by their magnitude, to uncover the large tusks, to prevent injury of the lips in seizing the prey, and to add ferocity to the aspect to intimidate and overcome that prey. The muscles of their short and thick neck are strong, to enable them to carry off their prey entire, or to tear it to pieces, as those of their shoulder and arm are powerful, to enable them to grasp or hold down

their prey, or to strike it to the ground, and they assist in bending forwards the trunk in striking, by their large *recti abdominis*, which here extend forwards to the anterior end of the sternum. The great extent of the fleshy part of their *diaphragm* aids their rapid and extensive respiration. The central tendinous portion of the diaphragm is much more extensive, and consequently the muscular part less, in the ruminating and other herbivorous quadrupeds. The muscles of the lower jaw in the cheiroptera and the levators of the upper lip are generally strong, as in the carnivora, and most of them are nocturnal predaceous animals, but as they pursue their prey through the air, the muscles proceeding from their scapula, their clavicle, and their sternum, to the humerus are of great size and strength, and the flexors of their carpus and fingers send down very long and thin tendons to the lengthened phalanges of the fingers, so as to lighten the distal extremities of the hands, and to adapt them for progression through so rare a medium. The quadrumanous animals being organized for a semi-erect position, and climbing movements, have the flexor muscles strongly developed on all their extremities, and the lengthened form and feebleness of the extensors of their posterior extremities, as the *glutei* muscles, the *recti femoris*, the *vasti*, the *gastrocnemii*, and other extensors, so large in the human body, produce that smallness of the nates, the thighs, and the calfs, so characteristic of this climbing frugivorous order. The muscles of the jaws and of the neck are strongest in the baboons, where the trunk is most adapted for the horizontal posture, and the ferocity and general strength are almost those of carnivora. The flexors of the coccygeal vertebræ are most powerful in the long prehensile tail of the *ateles*, or spider-monkeys of America, in which the long *recti abdominis* are still destitute of tendinous intersections, as in many of the inferior mammalia. From the vertical position of the human trunk on the posterior extremities, and the freedom and flexibility of the arms the extensor muscles are most developed on the legs, and the flexors on the arms. The muscles also which support and move the spine, and those which embrace the visceral cavities, are proportionally strong in man, (Fig. 79.) The numerous flexors of the toes are here powerful, to enable the foot to sustain the weight of the

whole body in progression, and this organ is strengthened by its shortness, and by the fixed condition of its solid parts. The *gastrocnemii*, (79. B. *k*, *l*,) are large, and the *tendo achilles*,

FIG. 79.



(79. B. *m*,) is thick and strong, to raise the heel and the whole trunk in walking, and to preserve the tibia in a vertical position on the astragalus in standing. For the same reason the *rectus femoris* (79. A. *n*,) and the *vastus exturnus* (79. A. *n*,*) and *internus* (79. A. *n*,†) are large and fleshy, to preserve the femur erect upon the tibia, and the *glutei* muscles (79. B. *f*,) are of great magnitude, to preserve the pelvis and trunk vertical upon the femur. Hence the magnitude and rotundity of the calfs, the thighs, and the nates, so characteristic

of the human form. The *trapezius* (79. B. *a*,) the *latissimus dorsi* (79. B. *c*,) the *rhomboidei*, *serrati*, *sacro-lumbalis*, *multifidus spinæ*, and most of the muscles of the back or extensors of the spine are proportioned to the great weight which they have to sustain in the movements of the trunk. The flexor muscles of the ankle-joint, and those of the knee and of the thigh are generally thin, lengthened, and feeble, compared with the extensors of these joints, or when compared with their development in many of the inferior mammalia. The *obliqui* and the *transversalis abdominis*, here form strong muscular parietes for the support of the heavy abdominal viscera, the *recti abdominis*, are unusually short and thick in man, and divided by distinct, transverse, tendinous intersections, and the small *pyramidales* are more constant than in quadrupeds. The articulation of the head of the humerus is adapted for free and varied, rather than for powerful, movements, and the *pectorales* (79. A. *b*,) the deltoid (79. A. *e*.) and the scapular muscles, are short, broad, and of moderate strength, but the *biceps brachii* (79. A. *f*,) the *flexor carpi radialis* (79. A. *k*,) and *ulnaris*, the *supinator radii longus* (79. A. *h*,) the *pronator radii teres* (79, A. *i*,) and almost all the other flexors of the fore-arm and those of the fingers, are much more developed than the extensors of the same joint; so that while these extremities are unfit for supporting the trunk in a horizontal position, they have the form and movements best adapted for seizing or feeling outward objects, for manipulating the young, and for the various uses to which they are applied in social intercourse and in the arts. The great weight of the head, and its vertical position, unsupported by a ligamentum nuchæ, require the *recti* and *obliqui capitis*, the *splenius*, *complexus*, and *trachelo-mastoideus*, the *platisma myoides* (79. A. *a*,) the *sterno-cleido-mastoideus*, and nearly all the other muscles of the neck, to be proportionally strong for the support and movement of that heavy part. The teeth having little resistance to overcome, by the general softness of the food, the *temporal* and *masseter* muscles are of moderate size, and by the shortness of the jaws the ordinary muscles of the face are confined to a smaller extent of surface than in other mammalia, and their actions consequently produce impressions more numerous and diversified, and which are more visible from the nakedness,

the softness, and the generally light colour of the human skin. The moveable parts of the face into which the muscles are chiefly insertéd, are the lips and the eye-brows, from the relation of these parts to food, to speech, and to visual impressions ; and as the motions of those parts are regulated by present sensations, and are associated with corresponding conditions of the mind, they are the chief seats of human expression, in which we read the transient feelings of the moment, or the habitual tendency of the passions, or the inward workings of the soul.

CHAPTER FOURTH.

NERVOUS SYSTEM, OR ORGANS OF SENSIBILITY AND MOTILITY.

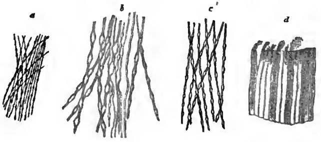
FIRST SECTION.

General Observations on the Nervous System.

The nervous system communicates to the muscles their energy of action, and to all the sentient parts of the body their power of feeling. By the rapidity of its action, and its extensive distribution through the body, it establishes an instantaneous communication between the most distant parts. It is chiefly by this system that animals are connected with surrounding nature, and there is no part of their economy which is more indicative than this of the condition of the whole organization, or of the grade which an animal occupies in the scale. The nervous system has been detected in every division of the animal kingdom, and almost in every class, and it is everywhere connected with sensation and motion. Its general form corresponds with that of the body, being short and disposed in a circular manner in the short round bodies of most of the radiated and molluscous animals, and having a

narrow and extended form in the more lengthened trunks of the articulated animals, and the vertebrata. The great central portion of the nervous system is perforated by the alimentary canal in the invertebrated classes, either in its middle, as in the radiata and the mollusca, or at its anterior extremity, as in the articulata ; but in the vertebrata the spino-cerebral axis lies wholly above the digestive cavity, by which it is nowhere pierced. The nerves of sensation and motion closely accompany each other, forming, by their union, chords or columns, or a spino-cerebral axis ; but the sympathetic nerves, appropriated to the more slow and regular movements of organic life, form a more isolated system, and these three systems are developed together, almost from the lowest animals. The nervous system consists of very fine tubular filaments, generally containing white-coloured opaque particles, much smaller than the globules of the blood ; these minute fibres do not ramify like blood-vessels, but continue uninterrupted from their peripheral extremity in the textures of the organs, to their proximal end in the cineritious substance of ganglia, or of the brain. The cineritious, or cortical matter is composed of a vascular plexus, in the meshes of which is an irregular granular pulp, and the fibrous arrangement becomes more obvious and regular at its junction with the white medullary portion. In the white portion of the brain, and in the nerves of the principal senses the ultimate component tubular filaments have a knotted or beaded appearance, from their numerous small dilations, and they appear to be empty, or to contain only a transparent homogenous fluid, as seen in the annexed figure of Ehrenberg (Fig. 80,) where (*a*) is a magnified view of the

FIG. 80.



knotted fibres composing the white matter of the human brain, (*b*) represents the coarser beaded fibres composing the human auditory nerve, and (*c*) exhibits those of the human optic nerve. This structure is observed on pressing fine sections of these parts between plates of mica or of glass, and viewing them through the microscope. This knotted structure of the minute filaments is seen also in the olfactory nerve, and in the sympathetic. The ordinary symmetrical nerves of sensation and of motion, throughout the body, are composed of tubular filaments of more equal calibre throughout their course, and which are filled with minute white globular particles, as seen in those of the human facial nerve (Fig. 80. *d*,) where the globular minute particles filling the neurilematous tubes are seen escaping from the cut ends of the filaments. This knotted appearance of the cerebral and sensitive filaments has been considered by some as resulting from the external aggregation of clusters of minute particles along the surface of chains of similar globules composing the ultimate nervous fibrils. These extremely minute fibrils, variously aggregated together by enveloping sheaths of condensed cellular tissue, but without anywhere anastomosing, constitute the nerves of sensation and of motion throughout the animal kingdom, and the spino-cerebral axis of the vertebrata. The nervous system is developed, like other organs of the body, from the periphery to the centre, and it presents great uniformity of plan in its adult conditions in the inferior classes, and in its transient embryo-forms throughout all the higher orders of animals.

SECOND SECTION.

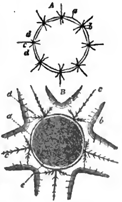
Nervous System of the Cyclo-Neurose, or Radiated Classes.

Many of the *polygastric* animalcules, as the *cercariæ*, are distinctly sensitive to light, and organs of vision, in form of minute red points, are seen in almost every genus. They appear also to possess an acute sense of taste, they distinguish, pursue, and seize their prey, they avoid impinging on each other while swimming, crowded in myriads, in a drop of

water; they contract and bend their body in every direction, and they increase or retard, or cease at pleasure, their progressive motion and the vibration of their cilia, like the muscular and gangliated rotiferous animalcules, yet nervous filaments have not been distinctly detected in the minute transparent bodies of the polygastrica. The numerous straight parallel jaws, seen in many of the genera, are opened and closed, advanced and retracted, with great quickness and precision, and all the movements of these minute animals appear to be as regular, methodical, spontaneous, and well-directed as those of many higher animals with obvious nerves. The transparency of the nervous filaments in all the minute forms of animals probably prevents our detecting in the polygastrica the rudiment of that form of the nervous system which is seen in the wheel-animalcules, and in the higher articulated classes. In the *poriphera*, the component particles of the nervous and muscular systems are probably diffused through every part of the soft cellular tissue of the body, which possesses the same living properties in every part, and is almost indefinitely divisible without destroying its vitality. The reproductive gemmules of these animals vibrate their cilia with great regularity and force ; they appear to be conscious of each other's approach, and can accelerate, retard, or cease their motions at pleasure ; they are sensitive to light, and appear to be guided by its influence in selecting the place of attachment most suited for the growth of each species : yet they exhibit no nervous or muscular filament in the gelatinous texture of their body. Many *polypipherous* animals, even of the simplest forms, are obviously sensitive to light, as *hydræ*, *lobulariæ*, *actiniæ*, and muscular fibres are distinctly perceptible in the polypi and other parts of most of the higher genera. The nervous system has been long known in the *actinia*, which is a large isolated naked polypus, closely resembling, in external form and internal structure, the polypi of *caryophilliæ*, *pavoniæ*, and many of the larger lithophytes. Nervous filaments surround the muscular foot of the *actinia*, beneath the stomach, and present minute ganglia in their course, from which nerves pass out to the circumference, and to the muscular folds which here possess great power of contraction. The same system probably exists in many other closely allied forms of polypi. The lowest

ciliograde *acalepha* possess great activity, are provided with numerous long tentacula exquisitely sensitive and contractile, exhibit distinct internal organs for digestion, circulation, and generation, and are found to be provided with nervous filaments and even ganglia around the œsophagus. In the *beroe pileus* (Fig. 81. A,) the nervous system is disposed around the mouth, at the lower extremity of the body, in form of a double filament (*a*,) with eight small white ganglia (*b*,) interposed between the eight longitudinal bands of cilia. From each of these ganglia a small filament proceeds upwards in a longitudinal direction (*c*,) towards the anal extremity of the body, and others pass out laterally and downwards to the projecting irritable lips surrounding the mouth. In the *medusæ* a nervous band, accompanying the marginal circular continuation of the alimentary cavity, is disposed around the irritable border of the mantle, with minute ganglia placed near the bases of the marginal tentacula. From each of these ganglia nervous filaments proceed to the nearest tentacula, along the bases of which they can be traced. Eight optic ganglia are perceived at the bases of the eight ocular peduncles, from which nerves proceed to the small red coloured marginal eyes, which they are observed to enter. Other ganglia are also perceived, near the ovaries, around the entrance to the stomach, from which nervous filaments, are seen passing downwards to the central groups of tentacula. From each optic ganglion two nerves proceed, which unite by a kind of decussation before they enter the eye; the eye is provided with a distinct crystalline lens, and the pigment is red-coloured, like that of most of the simplest forms of this organ. From the active movements of most acalepha in swimming through the sea, from their gregareous habits, the exquisite sensibility and contractility of their tentacula, the distinct development of their muscular fibres, and their perception of light, it is not likely that many are destitute of some form of this system, so general in its occurrence and so influential in the economy.

FIG. 81.



The *echinoderma*, like the acalepha, are all inhabitants of the sea, and, as in other aquatic animals, they present a development of the muscular and nervous systems, and of all the other organs of relation, inferior to that of animals of a corresponding grade, inhabiting the land ; their nervous filaments are also less white and opaque, less firm in texture, and less obvious than in the land animals. The distribution of the nervous system has been long known in several genera of this class, and it presents the same circular disposition as in the acalepha and other cyclo-neurose animals. In the *asterias* (Fig. 81. B,) which has but one opening of the alimentary cavity (*e*,) there is a small white opaque nervous chord (*a*,) passing round the mouth. From this circular chord a nerve (*c*, *c*,) is given off to each of the radiating divisions of the body, which passes along the middle of the lower parietes between the ambulacra, and gives filaments to the muscular suckers and other parts of the rays. Minute ganglia (*b*,) are observed at the points where these radiating nerves originate, and from each of these ganglia two nerves (*d*,) extend obliquely upwards along the sides of the stomach, and are confined in their distribution chiefly to the parts contained within the central disk of the body. A similar nervous chord is seen around the œsophagus of the *echinus*, which sends delicate white filaments to the complicated muscular and sensitive apparatus of the mouth ; other nerves are seen extending upwards from the same œsophageal ring, along the course of the vessels in the interior of the abdominal cavity. In the *holothuria*, where the axis of the body is greatly lengthened, and the animal reclines and moves on one side of the trunk, like the higher classes, where the calcareous shell is wanting, and the muscular system is most distinct and powerful, the nervous system is extensively distributed, and begins to manifest an approach to the helminthoid type. Interior to the osseous apparatus of the mouth is a white nervous ring around the œsophagus, from which nerves pass outwards to the large ramified tentacula around the mouth, and others extend upwards along the course of the eight strong longitudinal muscular bands. Fine white filaments are likewise seen passing inwards to the stomach and alimentary apparatus. In the *siponculus*, which is closely allied to the holothuria in internal structure and living

habits, but is much more lengthened and vermiform in outward shape, two of the minute longitudinal nervous filaments extending backwards from the œsophageal ring are developed only on one side of the body, like the abdominal nerves in the helminthoid articulata. Thus, in all the typical forms of this extensive class the nervous columns of motion and sensation are seen to form a collar around the entrance of the alimentary canal, which corresponds with the inverted position of the mouth, and the expanded, globular, or radiated form of the body around a short vertical axis. The lengthening of the axis in the soft naked apodal vermiform species of echinoderma necessitates a horizontal position of the trunk, and the nerves, yet unprotected by an osseous sheath, are, for safety, continued only along the inferior surface of the body. This introduces the distinction of dorsal and ventral surface of the trunk, unknown in the inferior tribes of radiata, where the parts are equally developed around a central axis, and where the nervous system presents the same peripheral development.

THIRD SECTION.

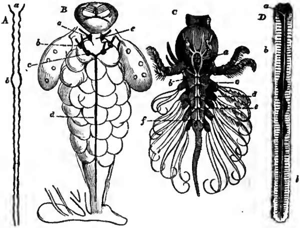
Nervous System of the Diplo-Neurose or Articulated Classes.

In the long cylindrical trunks of the helminthoid and entomoid classes, the nervous system partakes of the same lengthened form, and its motor and sensitive columns are extended for protection along the ventral or under surface of the body. This system is still contained in the same rings or segments which envelop the other viscera of the trunk in all the vermiform articulata, where the articulated members are scarcely developed from the sides; but in the highest entomoid animals of this great division the nervous columns are inclosed in a distinct thoracic osseous canal, separate from that which contains the other organs. And in all these classes the motor and sensitive columns appear to me to occupy the same inverted position, with relation to the spino-cerebral

axis of vertebrata, as that first shown by Lyonet in insects; the motor columns always lie above and in contact with the ganglionic, as shown by him in the *cossus* (Fig. 84. A. *b*, *c*.) All the other viscera of the trunk present the same inverted position; the heart-forming portion of the sanguiferous system occupies the dorsal surface, and the great nervous columns, the ventral surface of the alimentary canal, in the articulated classes. The position of these organs and of the whole trunk, and consequently the nervous columns, is reversed in the spini-cerebrata, where the great centres of the nervous system are inclosed in a distinct osseous sheath.

In the lowest of the helminthoid classes, the *entozoa*, where the animals remain, for the most part, permanently imbedded in the source of their nutrition, the nervous system is very imperfectly developed, and is little required. The more elevated forms of nematoid intestinal worms, as the *ascaris*, (Fig. 82. A,) present a slender double, white, nervous

FIG. 82.



filament, occupying the median line of the abdomen, and placed immediately within the inner longitudinal muscular tunic. This abdominal nervous chord in the long cylindrical body of the nematoid worms appears, from the close approximation and the smallness of its component parts, to consist

of a single filament, but it unravels its compound structure chiefly in two places of its course—where it meets with the vulva of the female, and separates its columns to embrace that orifice (Fig. 82. A. *b*,) and where it separates at the anterior extremity of the trunk to encompass the œsophagus (Fig. 82. A. *a*.) These nervous columns are more obvious on the large *strongyli* and *echinorhynchi*, where they present a similar form and distribution. Their anterior extremities generally ascend on each side of the œsophagus, so as to embrace that canal more or less completely with a nervous collar. The surface of the body, along which the nervous columns run in these animals, and in all the other articulated classes, is termed the ventral surface, from its being the inferior in the ordinary position of the body, and from the anus and other excretory orifices opening on that aspect of the trunk ; the anus, the valva, and the penis are placed on this surface in the entozoa. This simple form of the nervous system presented by the lowest articulated class, resembles the embryo form of this system in the higher classes of this division, and corresponds remarkably with the first perceptible form of the spino-cerebral axis in all the vertebrated animals, where it appears a double white streak on the outer layer of the germinal portion of the cicatricula. These simple worms, consisting solely of the trunk, present also the embryo-form of the whole body of the highest articulated classes. In the higher animals of this class, the epizoa, which adhere to some part of the external surface of aquatic animals, as in the *achtheres* and many others, the nervous system is more developed, and these animals generally possess rudimentary antennæ, and even eyes ; they have the two longitudinal nervous chords running separately and at some distance from each other, separated by the whole breadth of the alimentary canal. From the want of organs of sense on the anterior extremity of the body in most of the entozoa, the nervous system is very imperfectly developed in that direction, and although it often forms a ring around the œsophagus, it seldom forms a perceptible supra-œsophageal ganglion where these filaments meet.

In the *rotiferous* animals, where there is a complex muscular apparatus at the anterior extremity of the trunk, for the motion of the numerous large cilia, and another muscular apparatus for the movements of the strong lateral maxillæ,

the nervous system is most developed in that part of the body. There is generally in these wheel-animalcules, as in the *hydatina* (Fig. 82. B,) a distinct supra-œsophageal ganglion (*a*,) with smaller lateral ganglia (*b*, *c*,) surrounding the entrance of the alimentary canal (*e*) ; and from the anterior or inferior ganglia (*c*, *c*,) proceed the nervous columns backwards along the ventral surface of the trunk (*d*.) These abdominal nervous columns, as in the entozoa, are sometimes approximated to each other, and without perceptible ganglia in their course, and in others they are separated to a greater or less distance from each other, and have numerous ganglia developed along their sensitive columns. In the *hydatina*, the longitudinal nervous columns are united (82. B. *d*,) and without apparent ganglia below the alimentary canal. In the *diglena lacustris* the nervous columns are a little separated from each other, and present only one pair of ganglia immediately below the œsophagus, and another pair below the pyloric extremity of the stomach. The longitudinal ventral columns are much more separated from each other, in their whole course, in the *notommata clavulata*, and each of these lateral chords presents nine perceptible ganglia, in its course backwards to the posterior extremity of the trunk. These abdominal ganglia are symmetrically disposed in pairs, though removed laterally to a distance from each other on the inferior part of the trunk.

The nervous system of the *cirrhopods* (Fig. 82. C,) is symmetrically disposed in approximated columns (*b*, *c*,) along the abdominal surface of the trunk, with parallel pairs of ganglia regularly developed along their course, as in all the higher articulated classes. In the *anitifa* (Fig. 82. C,) we perceive a slender white nervous ring surrounding the œsophagus (*a*,) and sending out small filaments to the neighbouring parts, but scarcely forming a perceptible supra-œsophageal ganglion, from the imperfect development of the sensitive and masticating apparatus in these fixed and inverted testaceous or entomostracous animals. As the long, jointed and ciliated feet, with their thick muscular haunches, and supporting the branchiæ at their base, are developed from the sides of the posterior part of the trunk, the ganglia, like the nervous columns which connect them, are large in that part of the body, and correspond in position with the origin of the several pairs of legs (*b*, *c*, *d*, *e*, *f*.) So that

these animals, notwithstanding their molluscous exterior, fixed in a multivalve shell lined by a fleshy mantle, are connected with the articulated classes by the diplo-neurose character of their nervous system, and by all their other organs of relation.

The *annelida* present as great diversities in the extent of development of their nervous system, as in their exterior forms and their whole internal organization. In the minute transparent bodies of the *planariæ*, and in many of the simplest forms of aquatic worms, scarcely a trace of nervous columns can be perceived, although their organs of vision are often numerous and obvious, and even in the *naids* and some of the *nereids* the nervous chord along the middle of the ventral surface of the trunk appears as uniform and simple, as in the nematoid entozoa. The columns in the simpler annelides, as in the first larva state of the higher entomoid classes, scarcely present ganglionic enlargements in their course along the abdomen, or supra-œsophageal ganglia at their anterior extremity, from the general inferiority of their organization, and from the still imperfect development of their lateral appendices for progressive motion, and of their cephalic appendices for sensation or mastication. In the long cylindrical and muscular bodies of the air-breathing *earth-worms* (Fig. 82. D,) with their myriad of short and highly moveable segments, their exquisitely sensitive skin, and their minute rudimentary feet, we can perceive innumerable mixed nerves (Fig. 82. D. *b*, *b*,) proceeding laterally from the closely approximated nervous columns, but scarcely a ganglionic enlargement is developed in their long and equal course along the ventral surface of the trunk. In this highest of the helminthoid classes the nervous columns are still entirely enclosed in the cyclo-vertebral elements along with all the other viscera of the abdominal cavity. The abdominal chords of the earth-worm embrace the œsophagus at their anterior extremity, and form two distinct cephalic or supra-œsophageal ganglia (Fig. 82. D. *a*,) which supply nerves to the large muscular apparatus of the mouth, and to the long dorsal sympathetic. These two cephalic ganglia lie in contact with each other, are lengthened transversely, like those of insects, appear grey-coloured on the surface, and more white internally, and seem to be composed of minute globules

when examined under the microscope. The sympathetics are distinct along the aorta in the *nereides*, and the globular particles are seen in their neurilema. The ventral columns are separate from each other in the *sabellæ*. Where the body of the annelides is much developed transversely, as in the *leech*, the *sea-mouse*, the *pectinaria*, and many others, the ganglia along the columns, and the columns themselves are much more developed and distinct, and are visible at a much earlier period in the embryo. The abdominal ganglia of the leech, as shown by Weber, are quite obvious in the embryo of that worm while it is yet in the ovum. Where the setæ for progressive motion are large, numerous, and moved by strong extensor and retractor muscles, as in the *pleione* and many of the tubicolous annelides, the nervous columns and their ganglia are also large and distinct. The motor and sensitive nerves come generally from the same parts of the columns. The distribution of the minutest filaments are seen without dissection through the transparent and colourless body of the common *pectinaria*, and in most annelides the abdominal columns and ganglia, of a white colour and firm consistence, are obvious to the naked eye through the thin parietes beneath them. In some of the broad naked apodal annelides, where the segments of the body are very numerous and short, to facilitate their serpentine movements, as in the *leech*, the abdominal ganglia could not be safely accommodated in every ring of the trunk, and we find but one ganglion, of considerable size, for every three or four segments. These abdominal ganglia, about twenty-five in the leech, are more closely approximated to each other at the two ends of the nervous columns than in the middle, which already indicates the commencement of that longitudinal concentration of the ganglia so remarkable in the higher articulata, as the almost constant approximation of the lateral columns themselves on the median plain of the abdomen indicates development in a transverse direction, and a higher grade of this system than the detached condition of the columns seen in the lowest helminthoid animals.

The nervous system of the entomoid classes presents only a more developed condition of the same plan of structure presented by this system in the worms, and that of the most elevated insect or crab begins its development with the simplest helminthoid form, as the nervous system of man

passes through the simplest grades of that system presented by the lowest fishes. The larva of the insect, like the red-blooded worm, is almost a simple cylinder, soft, flexible, smooth, and equal throughout, and the nervous columns then manifest the same equal development from one extremity of the body to the other. The most helminthoid adult form of the whole body presented by the entomoid classes is that of the long equally developed *myriapods*, and the simplicity of their outward form is accompanied with a corresponding inferiority in the type of their nervous system, and of all their internal organs. Their nervous system is nearly that of the annelida and the larva; but as their consolidated segments develop stronger muscular members to support them on the land, their nervous columns and ganglia are encreased in size, to afford additional nerves to those enlarged extremities. On looking through the abdominal nervous columns of the *scolopendra*, we can distinctly perceive, notwithstanding the transverse approximation of all the parts, a distinct transparent line marking the original separation of most of the united ganglia. The globular cineritious particles, composing the ganglia, appear often united to form a round isolated mass in the centre of the ganglia, and the same opaque particles, when coagulated, are seen to occupy, in an interrupted manner, the interior of the sensitive columns. The motor columns I have found here of great size, as those shown by Treviranus and by Muller in the equally muscular body of the scorpion. The ganglia, like the segments, are nearly equally developed, and equidistant from one extremity of the chord to the other, excepting the first pair or supra-œsophageal, which give nerves to the long antennæ and to the large eyes, and the remarkably small round terminal ganglion below the anus. The intermediate transverse motor nerves, pointed out as respiratory nerves by Lyonet in the columns of insects, and by Morren in the annelides, do not here come off, as they do in the earth-worm, midway between the ganglia, but very close behind the ganglionic nerves. Four great nervous trunks originate from the columns on each side at each ganglion, and the second anterior of these branches, which is the largest, proceeds to the muscles of the legs, where I have traced it as far as the tarsal joint. Only two branches on each side proceed from the ganglionic space

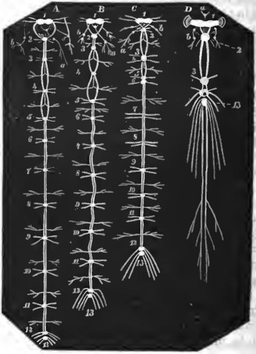
of the columns in the earth-worm, and one branch from each side in the middle of the inter-ganglionic space. The sympathetic and its ganglia are here extremely minute, as in the annelides from the lengthened, straight, and narrow form of all the nutritive organs. The second ganglion, or first sub-œsophageal pair, has a very lengthened form, and its nerves proceed backwards at a very acute angle, to escape from the large and long cephalic segment of the scolopendra. The nerves from the ganglia I have observed more yellow and opaque than the transparent and colourless filaments from the motor columns, as if some of the cineritious globules of the ganglia were continued into the sensitive portions of the mixed nerves. The great toughness and density of the neurilema, which envelopes the nerves of the myriapods and insects which breathe atmospheric air, is seen by the stiffness with which the most delicate and lengthened filaments project right outwards in a radiating manner from around all the ganglia; the nervous filaments are much softer in the crustacea, mollusca, and other aquatic animals, and the same difference is observed in the density of their muscular fibres. From the great size of the motor columns in the *scolopendra*, there is a distinct lateral longitudinal groove of separation between them and the inferior or sensitive chords, and on seizing the fourth or last pair of nerves from each ganglionic space, and raising them upwards, the large motor columns I have found to be nearly as easily separable from the sensitive beneath them, as those which I have demonstrated, for many years past, as the motor columns of the scorpion (Fig. 84. B. *a*, *a*,) and which have more recently been imagined to be respiratory nerves in the muscular tail of that pulmonated animal.

The abdominal nervous columns of insects have been correctly regarded by Lyonet, Straus, Dufour, Chiaje, and most others, as analogous to the spino-cerebral axis of vertebrata, and the first of these writers has described them seventy years ago, as similar in anatomical structure and physiological properties to the spinal chord of the highest animals. There are generally at first thirteen pairs of approximated ganglia corresponding with the original segments, and extended along the middle of the ventral surface of the body, as shown by Lyonet in the caterpillar of the *cossus*, and the œsophagus passes downwards

to perforate the connecting nervous columns, between the first and second pairs of ganglia, as in other articulated classes; so that the first pair only are supra-œsophageal or cephalic, and all the succeeding ganglia of the columns are beneath the alimentary canal. Those ganglia are at first, like those of the worm and the centiped, nearly at equal distances and of equal size, as the segments themselves of the young caterpillar. The columns and the ganglia originally separate on the two sides, early approximate transversely and unite, and a slow movement of the ganglionic matter is at length observed in a longitudinal direction to the parts of the columns where it is most required in the adult condition of the species. These *transverse* and *longitudinal* movements of the nervous matter so accurately described by Herold in the spinal columns of insects, proceed to a very variable extent, according to the degree of metamorphosis from the larva state to which the whole body is subjected in the different adult forms of this class. As in the myriapods, the first and second pairs of ganglia are here contained within the head, and the succeeding pairs are generally placed near the anterior limit of the segments to which they belong. The œsophageal ring thus formed by the columns between the two first or anterior pairs of ganglia is much wider during the voracious larva state of the insects than in their adult condition, (see Fig. 83. A, B, C.) The third pair of ganglia, placed in the prothorax, appear to be generally smaller than the fourth, and the fifth, in the metathorax, smaller than the sixth, as in the *cossus*. The ganglia contained in the abdomen of the entomoid classes, like the segments of that part of the trunk, are generally the least altered by development, from their primitive condition; but these are most changed in insects, and are often obliterated by the process of development, as shown by Straus in the coleopterous insects, (see Fig. 83. D,) and by Dufour in many of the hemiptera. The last pair of ganglia are generally the first to advance forward to unite with the penultimate pair in the larva state. In the annexed figures (Fig. 83. A, B, C,) are seen the common conditions of the nervous system in the larva, the pupa, and the imago state, and the changes produced in that system by the metamorphosis to the perfect state, as observed and described by Herold, twenty years ago, in the

papilio brassicæ. In the larva of that lepidopterous insect (Fig. 83. A,) the columns are lengthened, the ganglia widely separated, and nearly equal, with a large ring between the cephalic (1,) and the first infra-œsophageal (2,) ganglia. The first or cephalic ganglia (A. 1,) were observed by Lyonet to give off eight pairs of nerves, which pass chiefly to the organs of the senses, besides the two columns which connect them

FIG. 83.



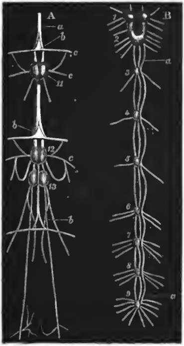
with the second pair of ganglia (A. 2.) They give off, likewise, filaments to the small lateral ganglia (A. *b*,) of the head, and to the commencement of the sympathetic series of ganglia (A. *a*,) as shown by Lyonet in the *cossus*. Between all the succeeding pairs of ganglia a solitary branch is seen coming off from each side of the motor column, which interganglionic nerves were shown by Lyonet to be distributed

on the muscles and the minutest ramifications of tracheæ for respiration. These inter-ganglionic nerves come off generally at a greater distance from the ganglia in insects and crustacea, and in worms, than in the myriapods and the arachnida. The last pair (A. 13,) of ganglia are already approached to those which precede them (A. 12.) In the pupa state of this moth (Fig. 83. B,) the approximation of the segments has not only shortened the total length of the columns, but has caused them to assume a puckered or curved appearance, where they lie free between the ganglia; the shortening of the whole trunk during the metamorphosis thus obviously takes place more quickly than the corresponding changes of the nervous system. The œsophageal ring is diminished, the cephalic ganglia are enlarging and extending transversely for the myriad of developing eyes, and the thoracic pairs of ganglia are approaching to each other, preparatory to their uniting together at the part best suited to send nerves to the yet undeveloped thoracic members. The third pair of ganglia often advance to unite closely with the second pair, the fifth to unite with the fourth pair, and the seventh pair to unite with the sixth, during the passage to the imago state, and several, or the whole, of the ganglia which succeed these in the cavity of the abdomen, entirely disappear, while the motor and sensitive nerves still continue to come off from the same parts of the columns, as seen in the nerves of the perfect insect (Fig. 83. C. 7, 8.) In the imago, or perfect state of the insect, (Fig. 83. C,) the loose inter-ganglionic portions of the columns, which were zig-zag in the pupa, have assumed a straight and shorter form, the two last pairs (12, 13,) have coalesced into one ganglion, and advanced from their original position, the cineritious matter has disappeared from two pairs of the abdominal ganglia (7, 8,) without affecting the original origins of their nerves; four pairs of ganglia (6, 5, 4, 3,) have coalesced at two points of the thorax, to supply nerves to the muscles of the legs and wings; the second and first pairs of ganglia (2, 1,) have approached in the head, and diminished the diameter of the œsophageal ring, the cephalic ganglia (C. 1,) have enlarged and extended transversely, to form the expanded optic lobe in each orbit, and the accessary nerves (C. *b*, *b*,) and the great sympathetic (C. *a*,) running back-

wards in the median plain above the alimentary canal, have assumed an encreased development, as shown by Lyonet and Straus, and thus more intimately united all the segments and parts of the body by encreasing these bonds of connexion between all the organs and functions of vegetative or organic life. The same kind of change in the whole condition of the nervous system, effected by the metamorphosis of the insect, is seen in Straus' figure of the adult or imago state of that system in the *melolontha vulgaris* (Fig. 83. D,) where the usual concentration of the nervous matter in the head and thorax has proceeded to a greater extent than in the *papilio*. The ganglia of the abdomen are most frequently preserved through all the stages of life in the lepidopterous and the hymenopterous insects, and in those which have the segments of the abdomen the least altered from their larva condition by the process of metamorphosis. But in this coleopterous insect (Fig. 83. D,) where the adult form of the whole body is very remote from that of a caterpillar or of an annelide, all the ganglia have disappeared from the short round abdomen, and have accumulated in three contiguous masses in the middle of the thorax, from which the nerves radiate to the organs of motion, and extend backwards into all the segments of the abdomen. The cephalic ganglia (1, 2,) have also encreased above and below the œsophagus, the cerebral lobes (1,) passing laterally into the large compound eyes, and the great sympathetic longitudinal series of supra-œsophageal ganglia (*a*,) with their accessary lateral filaments and ganglia (*b*,) have advanced still more in their development. The greatest change of the nervous system, however, from its original larva condition, effected by the metamorphosis in insects, is that presented by the *pentatoma*, the *cicada*, and some others where all the ganglia of the columns have accumulated in two points, above and below the œsophagus, in the head and in the middle of the thorax; thus nearly approaching to the highest condition presented by this symmetrical nervous system in the most elevated tribes of crustacea, and to the cyclo-gangliated character so general in the molluscous classes. Although during this rapid series of changes the last and the penultimate pairs of ganglia are generally the earliest to approach and unite, they are at first distinct pairs like those

before them on the columns, as seen in the annexed figure by Lyonet, of the three last pairs of ganglia and of the nerves which come from them, in the larva of the *cossus ligniperda* (Fig. 84. A.) The upper portion (*a*,) of the columns is seen to give off the inter-ganglionic nerves (*b*, *c*,) which Lyonet showed to be distributed on the respiratory organs after receiving a small connecting branch from the first pair of

FIG. 84.



the next succeeding ganglionic or mixed nerves (11. *c*, *c*.) This arrangement of the motor and ganglionic nerves is represented at each inter-ganglionic space along the columns. It was likewise shown by Lyonet that these motor nerves (13. *b*,) proceeding to the lateral muscles and respiratory organs, come from a tract occupying always the upper surface of the columns, and distinctly passing over the upper surface of at least the last pair of ganglia.

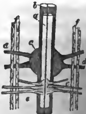
It was, however, in the class *arachnida* that Treviranus first pointed out, more than twenty years ago, in the nervous system of the *scorpion* (Fig. 84. B,) the continuity of this motor tract (84. B. *a*, *a*,) over the upper surface of the whole extent of the columns, and I have long shown the same structure to pervade the articulated classes. The nervous system, like most other parts of the arachnida, presents an intermediate condition of development betwixt that of most insects and that of the higher crustacea. While the nervous columns of the scorpions, with their accompanying series of ganglia, are lengthened in form, like those of lepidopterous insects, the same parts in the spiders have the concentrated form which they present in the highest crabs, with their symmetrical ganglia concentrated in two points of the body. The motor columns are large in the scorpion, as in the scolopendra, and are here also easily separated from the sensitive columns beneath them, excepting where they pass over the surface of the ganglia, from which they cannot be detached. The whole of the columns are less intimately connected together, and the inter-ganglionic spaces are larger in the cavity of the abdomen than in the round narrow muscular tail, or caudal portion of the trunk. In this posterior part of the body the motor columns are proportionally more flat and more expanded over the ganglionic chords, as they are likewise in crustacea and other articulated classes. Besides the cephalic, or supra-œsophageal ganglia (Fig. 84. B. 1,) and the large infra-œsophageal mass of concentrated ganglia which radiates nerves to the five pairs of legs, there are seven pairs of closely approximated ganglia (84. B. 3—9,) of a lengthened form, disposed along the inferior surface of the trunk. The motor or respiratory nerves come off at the ganglia, as in the myriapods, and not at a distance from the ganglia, as the inter-ganglionic nerves of insects and crustacea. Towards the caudal extremity of the scorpion, the mixed nerves of the columns diverge suddenly in numerous minute fasciculi from the sides of the ganglionic spaces (84. B. *g*. 8.) But as we advance in the trunk we find the whole of the mixed nerves coming off in one large fasciculus from each side of each double ganglion (84. B. 5, 4, 3.) The first and second pairs of ganglia (84. B. 1, 2.) form a large, white, soft nervous mass occupy-

ing the anterior and lower part of the trunk, immediately beneath the eyes; this lobed mass is perforated obliquely by a small aperture through which the œsophagus passes to the stomach. I have generally found the ganglionic spaces of the columns of the scorpion, as in many insects, closely encrusted with small white lobes of adipose substance, in which the œsophageal nervous collar is likewise imbedded. The infra-œsophageal ganglia are much larger than the first pair which have few and small parts to supply. This second pair of ganglia, composed of all the ganglia of the extremities (84. B. 2,) is protected behind by a cartilaginous arch, through which the columns pass to the third pair of ganglia, like the consolidated internal arch for the nervous column in the thorax of crustacea. Numerous large nervous branches proceed backwards along the inferior surface of the abdominal cavity from the infra-œsophageal ganglia (84. B. 2,) beneath the motor and sensitive columns, as represented, many years ago, by Treviranus and Muller, in their views of these columns in the scorpion. In the short and rounded body of the spiders, the supra- and infra-œsophageal ganglia form a large nervous collar around the œsophagus, the inferior portion of which, as in the scorpions, forms a large lobed mass, from which all the nerves of the extremities radiate. The supra-œsophageal ganglia are small here also, from the imperfect development of the organs of the senses and of mastication. The ganglia of the abdomen, which are extended along the trunk separately in the scorpions, are accumulated into a single mass in the spiders, and placed near the anterior part of their short and wide abdominal cavity. Thus the extent of concentration of the nervous columns of arachnida, and the extent of distribution of their unsymmetrical or sympathetic system, correspond with the high condition of the other systems in this class, and while they vary in the different tribes, they approximate the more elevated forms to the highest insects and crustacea.

In the numerous and diversified class of *crustacea* we meet with every condition of the nervous system, from that of the lowest annelide, or the earliest larva state, where scarcely a filament is yet perceptible in the place of the nervous columns, to that concentration of the nervous ganglia around the œsophagus, which connects the highest articulata with the mol-

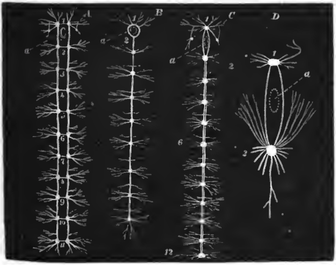
luscous classes. The motor and sensitive columns are seen on a larger scale in the crustacea, and they occupy the same relative position as those long known in the other entomoid classes. The supra-œsophageal ganglia are generally larger than those of arachnida, and smaller than those of insects; they are, for the most part, united into a single cerebral ganglion devoted chiefly to the large organs of the senses, and their nerves unite with the sympathetic, as in insects and mollusca. The nervous ring of the œsophagus is here very wide, but the columns are small which form it, and they give off large branches to the stomach and the sympathetic while they pass along the sides of the œsophagus. The ganglia of the cephalo-thorax vary much in their number, their magnitude, and their degree of approximation according to the form of that part of the trunk, and the size of the several pairs of legs. The motor columns are seen in the large macrourous decapods, as in the post abdomen of the lobster, (Fig. 85. *a*,) passing over the upper surface of the sensitive columns (*b*,) and their ganglia (*c*,) as a broad, thin, white, fibrous layer, and giving off lateral branches chiefly behind each pair of ganglia. The largest trunks and mixed or moto-sensitive nerves of the columns come off at their ganglionic spaces (*c*, *d*.) These inter-ganglionic motor nerves (*e*, *e*,) in the posterior portion of the trunk come off at a greater distance behind the ganglia, as they do in insects; but as we advance to the fore part of the body, their origins become approximated to the ganglia. The posterior terminal pair of ganglia have generally a high position, and are of great size where the caudal appendices of the trunk are much developed, as in the long-tailed decapods. The same transverse and longitudinal approximation of the nervous columns and their ganglia, seen in the inferior articulata, is perceived in the development of the crustacea; and the most concentrated form of the nervous system met with in the highest brachyourous decapods, gradually acquires this concentration of all its ganglia in two points of the body, above and below the œsophagus (Fig. 86. D,) by passing through all the inferior conditions which present themselves as permanent or adult forms in this class.

FIG. 85.



Many of the lower amphipoda and isopoda have the segments nearly equally developed from the anterior to the posterior extremity of the trunk, and this equal development is seen also in the nervous columns and ganglia of these segments, as shewn in the annexed figure of those of the *talitrus locusta*, or common sand-hopper (Fig. 86. A.) The slender longitudinal columns and the minute ganglia along their course here remain distinctly separated from each other by a small space on the median plain; the ganglia are nearly of the same size from the first pair (1,) above the œsophagus (*a*,) to the caudal pair (11,) and the pairs are almost equidistant along the whole trunk, in a longitudinal direction. This simplest adult form of the nervous system shown by Audouin and Edwards in the *talitrus*, has been pointed out likewise by Rathke in the *idotea*, and the same is seen through the transparent bodies of many other minute isopods. The same form of the nervous columns is seen in the highest crustacea while yet in their embryo condition in the ovum. In the short and broad trunk of the *cymothoa* where the legs are still equally developed along the whole sides of the body, the nervous columns (Fig. 86. B,) have already approximated to

FIG. 86.



touch each other on the median plain, and the ganglia on the two sides have coalesced to form a single chain along the middle of the abdominal surface of the body. The ganglia are still nearly equidistant, and equally developed along the columns; but where the minute posterior tapering segments of this animal have advanced and united, their ganglionic matter appears likewise to have been carried forwards to enlarge the ninth or terminal ganglion (Fig. 86. B.) The transverse concentration of the columns and ganglia towards the median plain, thus seen in the lowest crustacea, is succeeded in higher species by a longitudinal movement of the nervous matter directed, as we have seen in inferior classes of articulata chiefly to two points of the body, the head and the thorax, from which the largest and most important appendices of the body, whether for sensation, mastication, or progressive motion are developed. In the long-tailed decapods, as the lobster (Fig. 86. C,) and the cray-fish, not only is the sympathetic system of nerves derived from the lateral ganglia of the stomach, greatly developed, as shown nearly twenty years since by Succow, and the ganglia and columns have coalesced and met transversely along the whole body; but in the region of the thorax, from which the five pairs of large extremities are developed, the ganglia (Fig. 86. C. *a.* 6,) have both enlarged in size above those of the post-abdomen (C. 6—12,) and considerably approximated to each other in a longitudinal direction. In the higher entomoid articulata the segments first coalesce on the anterior and posterior portions of the trunk, and hence the enlarged form presented by their cephalic and caudal ganglia, independent of the great size often attained by the appendices developed from the terminal parts of the body. The ganglia and columns of the post-abdomen in these macrourous decapods (C. 6. 12,) as shown by Succow, retain much of their primitive simple form, like the segments and appendices of that portion of the trunk; but the last ganglion (C. 12,) advanced to the penultimate segment, is here of great size, from the magnitude of the swimming appendices developed from the two caudal segments. The thoracic ganglia and columns are excluded from the general cavity of the trunk, and are enclosed in a distinct canal with solid calcified parietes prolonged inwards from the exterior shell. The most concentrated form of the nervous system met with in the crustacea and its

highest condition presented by this articulated division of the animal kingdom is that found in the short and broad trunks of the brachyourous decapods (Fig. 86. D,) where all the symmetrical ganglia of the columns are generally collected into two masses, the one in the head, and the other in the centre of the cephalo-thorax, and where the motor and sensitive columns are almost confined to a nervous band around the wide œsophagus. The anterior of these, or the supra-œsophageal ganglion (86. D. 1,) is comparatively small in the brachyourous decapods, from the smallness of the cephalic appendices, which it supplies with nerves. The infra-œsophageal nervous mass (86. D. 2,) is of great size, consisting of the whole chain of ganglia, which was originally extended along the body behind the œsophagus, and is favourably situated between the haunches of the legs, under a strong internal osseous arch, in the centre of the trunk. It sends out numerous branches to the surrounding viscera, and to the five pairs of legs which radiate from around that point, and the columns are prolonged backwards ramifying along the short slender post-abdomen, as a simple nervous chord. There are many intermediate conditions of these nervous columns and ganglia between those of the *astacus* (Fig. 86. C,) and of the *maia* (Fig. 86. D,) some of the macrourous decapods having the thoracic ganglia much more approximated than in the former, and many of the brachyourous species having them less concentrated into a mass than in the latter, and similar links are observed to connect together the typical forms of this system in the other orders of crustacea, and throughout all the articulated classes. Thus the most elevated form of the nervous axis met with in this division of the animal kingdom begins its development with two simple abdominal filaments, like the lowest helminthoid form of entozoa, and by a gradual process of concentration proceeding transversely and longitudinally from the peripheral to the central parts, it arrives at the cyclo-gangliated character of the molluscous classes, with its great symmetrical ganglia confined to the œsophageal ring.

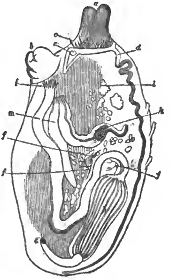
FOURTH SECTION.

Nervous System of the Cyclo-gangliated or Molluscous Classes.

The nervous system is distinctly developed and provided with several ganglionic centres, in all the molluscous classes from the lowest compound forms of *tunicata* to the highest of the *cephalopods*, and notwithstanding the remarkable diversity of form which the animals of this division present, we can trace a certain similarity of character and unity of plan in the development of this system, and in its typical forms, throughout all the cyclo-gangliated classes. As all molluscous animals are aquatic, excepting a few of the gasteropods, their nervous fibres present the same soft and pellucid character observed in other aquatic invertebrata, which often renders it less easy to trace their ramifications and to detect their plan of distribution, than to follow the denser opaque fibres of the air-breathing tribes, and has repeatedly caused them to be mistaken for sanguiferous or chyliferous vessels. In the short and broad trunks of the animals of this division, as in the round bodies of the radiata, the nervous system is characterised by a tendency to accumulate around the entrance to the alimentary canal, but from the high position of the molluscous classes in the scale, their nervous œsophageal collar is provided with distinct and often numerous ganglia. The same columnar arrangement of the great nervous centres, which I have long observed and described in most of the articulated classes, I have found to exist also in the molluscous, though in a less extended or recti-lineal form. In the tunicated and conchiferous animals the columns are chiefly disposed beneath the alimentary canal; in the gasteropods and the pteropods they are more equally distributed around the entrance to the stomach; and in the more elevated forms of cephalopods they at length mount to that supra-œsophageal position which they preserve in all the vertebrata where

they cease to embrace the alimentary canal. In the lowest compound *tunicated* animals as in the *botryllus* and the *pyrosoma*, there is a small round white coloured opaque ganglion, within the muscular tunic of each of the component animals, placed near the entrance of the respiratory sac, and between that orifice and the anal. When we compare the position of the thoracic cavity (Fig. 87. *l.*) and its apertures (*a. b.*) in the tunicata with those of the conchifera, we perceive that this single median ganglion (*e,*) is situate on the ventral side of the body, though at some distance from the entrance (*g.*) to the stomach. (*h.*) This ganglion is seen in the same position in the minute component animals of the *polyclinum*, the *aplidium*, the *didemnum*, the *eucœlium*, the *synoicum*, the *diazona*, and the *distoma*. In the larger forms of simple *ascidiæ* as in the *boltenia*, *phallusia*, and *cynthia* (Fig. 87,) this last ganglion (*e.*) has generally a more lengthened oval form, and I have sometimes found it bifid both before and behind, where two nervous branches come off from each of its extremities. The two anterior nervous branches are larger than the two posterior which pass backwards on each side of the anal opening (*b.*) of the muscular tunic. The anterior pair encompasses the respiratory orifice (*a*), sending off filaments to the fringed and highly sensitive tentacula (*c.*) which guard this thoracic aperture; these two branches again meet behind the orifice (*d.*) and continue as a broad chord along the dorsal part of the muscular coat or mantle. Besides this ganglion, which is connected with the muscular apparatus of the respiratory sac and its openings, like the posterior pair of ganglia in the conchifera which are also sometimes united into one, three

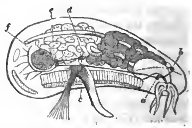
FIG. 88.



other ganglia are observed in the abdominal cavity, extended, as the ganglionic columns in the succeeding class, between the alimentary and respiratory cavities.

The nervous columns of the *conchifera* are almost confined to a sub-œsophageal position, and extend along the inferior or ventral surface of the abdominal cavity, above the respiratory sac; they are most detached from each other at their anterior part, and often continue separate through their whole course. The motor or simple colums, which I have generally found more transparent and colourless than the ganglionic, keep in contact with the sensitive chords, but sometimes they occupy a lateral position, passing over the sides of the ganglia, especially the last pair where the two kinds of nerves are most obvious. On opening the respiratory sac of a conchiferous animal, as of the common *muscle, mytilus edulis* (*Fig.* 88) and throwing aside the branchiæ, the foot, and the pectinated lateral prolongations of the lips, we perceive two large white ganglia (88. *a.b.*) placed on the lower and lateral parts of the mouth, resting on the peritoneal covering of the stomach or of the liver which envelopes it, and sending upwards and forwards numerous large branches to the lips and neighbouring parts, and to the sympathetics. Two of these branches, after encompassing the short œsophagus, often meet above that passage, and form a distinct supra-œsophageal or cerebral ganglion, and two other branches passing inwards from the same ganglia, beneath the stomach, sometimes form another double ganglion on the median plain, close to the first sub-œsophageal pair (88. *a. b.*) The double nervous columns continue their course backwards, from these anterior lateral ganglia, running on the same plain along the inferior surface of the abdominal cavity, to the broad expanded base of the muscular foot, where the middle pair of ganglia are placed. These abdominal or pedal ganglia (88. *c. d.*) are the most variable in

FIG. 88,



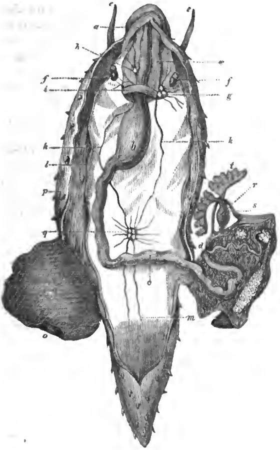
size, and correspond in their development with the presence or the magnitude of the foot which receives branches from them. The columns which connect these two pairs of ganglia are separated from each other on the median plain by a space, which varies according to the lateral extension of the trunk in the different species; they are generally parallel and near to each other in their course. The two symmetrical columns of ganglionic and simple nerves, continuing backwards beneath the ovary to the inferior surface of the great adductor muscle of the valves, meet with a third pair of infra-abdominal ganglia (88. *e.*) which are the most approximated to each other, and are often united into a single lobed ganglionic mass, as in the *pecten maximus*. In this large *pecten* it is easy to perceive that the motor portion of each of the two converging columns passes laterally over the surface of this large compound ganglion placed on the median plain, under the middle of the large adductor muscle of the valves. This pair of ganglia (*e*) appears to vary in size with the magnitude of the adductor muscle, and the extent of the palleal margins and branchiæ which receive nervous branches from it. The columns which pass backwards from the posterior ganglia, soon divide into numerous branches which supply this part of the trunk, and the largest nerves (*f.*), continued upwards along the adductor muscle from the columns, are observed to extend, on each side of the rectum, to the margins of the mantle, and to supply the ciliated and fringed orifices of the abdominal and thoracic cavities, and they send large branches to the branchiæ. The ganglia, which are most obvious on first opening the valves of the conchifera, are the posterior pair placed on the adductor muscle, and these have generally been described and figured by Poli as the centre of this system, which he mistook for the chyliferous system of these animals; the same pair has been uniformly designated and represented by Chiaje as the brain of these acephalous mollusca; but both these authors have accurately represented their forms and the distribution of their numerous diverging branches. These two ganglia are connected by a transverse band on the posterior adductor muscle of the broad *arca noæ*, the nerves of which have been minutely traced

and represented by Poli, as extending over the branchiæ and the posterior portion of the mantle. These posterior ganglia, situate on the great adductor muscle, and sending forwards branches to the gills, are very remote from each other in the *avicula;* they are separate in the *mactra* as in the *mytilus,* they are partially joined into a quadrilobate mass in the *cardium* and the *solen,* they form a single ganglion in the *spondylus* as in the *pecten,* and they form by their union a transverse thick nervous band on the large abductor of the *pinna.* The first sub-œsophageal pair of ganglia (88 *a. b.*) with their numerous anterior branches and their two columns extending backwards to the posterior ganglia (88. *e*) have been accurately traced and represented by Poli in different species of *solen.* Small ganglia are observed in the conchifera, as in the tunicata and in the articulated classes, on other nerves besides the two great sensitive columns. The visceral or sympathetic nerves appear to receive their principal branches from the nerves of the first sub-œsophageal pair of ganglia, as they have been long known to receive their principal trunks from those of the two corresponding lateral ganglia of the stomach in the crustacea.

From the great development of the organs of the senses and of mastication at the entrance to the œsophagus in the *gasteropods,* their nervous axis is much more concentrated and developed in that situation than it is in the conchifera; and from this general advancement of the great nervous centres to the head of these animals, we commonly observe a proportional diminution in the extent of their two symmetrical sub-ventral nervous columns. In the short and broad bodies of the gasteropods, the symmetrical columns are still generally separated from each other by a variable space along the median plain, as in the conchiferous mollusca, but as the general form and structure of the animals of this class vary remarkably, we find a corresponding diversity in the form and disposition of the great centres of nervous energy. In the simple form of the nervous system presented by the *carinaria mediterranea* (Fig. 89,) there is a close analogy with the ordinary disposition of the symmetrical detached nervous columns along the ventral surface of the abdomen in the inhabitants of bivalve shells. Lobed ganglia (*g. h,*) are

observed in this animal at the sides of the œsophagus (*) and a transverse nervous band (*i*,) connecting them, and encompassing that passage. From this nervous œsophageal ring (*i*,) the two optic nerves pass laterally to the eyes (*f*,*f*,) and

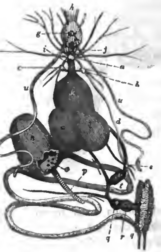
FIG. 89.



the tentacular branches pass upwards and forwards to the long slender tentacula (89. *e*, *e*.) Numerous branches extend downwards and laterally, to ramify on the muscular parietes of the abdomen, and two principal trunks (*k*, *k*,) ex-

tending backwards along the ventral surface of the abdomen, like the great nervous axis of conchifera, meet with a large compound quadrilobate ganglion (*q*,) behind the stomach (*b*,) and above the diverging muscles of the compressed pinniform foot (*n*, *o*.) These two sub-ventral, detached and converging columns (*k*, *k*,) extending from the œsophageal collar to the middle or pedal ganglia (*q*,) can be traced backwards from these ganglia along the lower surface (*q*, *m*,) of the abdominal cavity and beneath the intestine (*c*, *d*,) to near the caudal extremity of the trunk. Another branch is described by Chiaje as a sympathetic extending directly backwards from the brain, or œsophageal collar, and spreading on the viscera without passing to the quadrilobate ganglion (*q*.) Numerous branches come off from the periphery of the pedal ganglia (*q*,) to ramify on the muscles of the foot, and the surrounding parts. The pedal ganglia (*q*,) have been regarded as sympathetic, but from their whole relations to the rest of the nervous system, and from the form and position of the great trunks (*k*, *k*, *m*,) connected with them, they appear more analogous to the symmetrical sub-ventral ganglia of conchifera, and of the articulated classes. The lateral ganglia of the nervous œsophageal collar are generally the parts

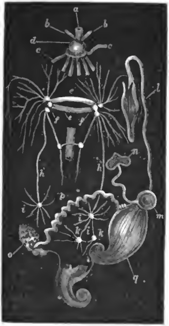
FIG. 90.



from which the two principal nervous chords extend backwards beneath the abdominal viscera in the gasteropods as in the bivalved mollusca, as seen in the annexed figure of the nervous system of the *aplysia fasciata* (Fig. 90.) In the *aplysia*, as in many of the higher forms of gasteropods there is a large median supra-œsophageal ganglion (*a*,) from which the organs of the senses receive their nerves, and from this single superior ganglion (*a*,) proceed downwards and laterally two nervous bands to connect it with the usual pair of lateral œsophageal ganglia (*b*, *c*.) Two nervous branches (*f*,) likewise proceed downwards and forwards from the cerebral ganglion (*a*,) to form a small anterior collar around the œsophagus (*i*,) and an inferior single ganglion (*g*,) is seen beneath the muscular bulb of the œsophagus, where these branches meet. The posterior large nervous collar is completed by an inferior transverse band passing between the lateral ganglia (*b*, *c*,) and beneath the œsophagus (*i*.) From the lateral œsophageal ganglia (*b*, *c*,) two nervous trunks (*d*, *d*,) extend backwards beneath the divisions of the stomach (*k*, *l*, *m*, *n*,) and along the ventral surface of the abdomen to near the bulb of the aorta (*t*,) where they meet with a single ganglion (*e*,) considered, from its position, its distribution and its attachment to that arterial trunk, as a sympathetic ganglion. The cerebral ganglion (*a*,) placed above the œsophagus, and connected through the lateral ganglia (*b*, *c*,) with these two longitudinal columns, has a quadrangular form, a reddish brown colour, and is enclosed in a tough cranial membranous capsule immediately above the posterior end of the bulb of the œsophagus. The same reddish coloured nucleus and granular structure are seen in all the ganglia of the *aplysia*, and from the toughness of the neurilematous covering of the ganglia and nerves they can be easily injected like vessels, as in most other molluscous animals. The lateral ganglia (90. *b*, *c*,) have each a trilobate form, and the nervous bands which connect them with the brain have a distinct appearance of separate component columns. There are two filaments which proceed backwards from these lateral ganglia, like the origins of the sympathetics of crustacea, and which here form by their union an arch around the trunk of the aorta. The anterior bilobate sub-œsophageal ganglion (90. *g*,) gives off eight nerves to the œsophagus, the salivary glands and

the muscles of the mouth. The two lateral ganglia are connected together by a broad nervous band, which passes below the œsophagus and completes the posterior ring around that passage. The muscles of the head, the superior tentacula, and the small eyes, receive their nerves from the cerebral ganglion (*a*.) The optic is a branch from the large tentacular nerve on each side. The nerves from the lateral ganglia are spread chiefly on the muscular parietes of the trunk, and those from the aortic ganglion (*e*,) are observed ramifying on the liver, the intestines, the branchiæ, and the generative organs. The aorta receives a minute branch from the two anastomosing filaments of the lateral ganglia, which embrace it, and a second ganglion almost imperceptible, is found on one of the branches proceeding from the great abdominal sympathetic ganglion. The sympathetic ganglia are also distinct in the *scyllæa*, the *glaucus*, and many other small naked gasteropods. The nervous œsophageal ring of the *haliotis* has two lateral ganglia which supply nerves to the tentacula, the pedunculated eyes, and other parts of the head, and presents below the œsophagus a large median ganglion from which a series of long nerves extend backwards along the inferior surface of the abdomen, as in the *carinaria*, and the same plan of distribution is seen in the nervous system of the *patella* and many similar forms. In the *bulla lignaria* (Fig. 91,) there is a small lobed ganglion anterior to the usual cephalic ring (*e*,) and which is situate below the bulb (*d*,) of the œsophagus (*a*,) behind the salivary glands (*b*, *b*,) and anterior to the insertions of the diverging muscular bands (*c*, *c*,) of the bulb of the œsophagus. This ganglion is situate like the small anterior infra-œsophageal ganglion of the *aplysia*. The cephalic ring (*e*, *e*,) enveloping the œsophagus, behind this single ganglion, has two large trilobate ganglia (*f*, *f*,) at its sides, which send numerous branches to the surrounding muscular parts, and two long branches (*h*, *h*,) extend backwards from them along the sides of the abdomen to two symmetrical sub-ventral ganglia (*i*, *i*,) placed above the muscular foot. Behind these are two sympathetic ganglia (*k*, *k*,) which send filaments to the digestive organs, the ovary (*o*,) the oviduct (*p*,) the uterine sac (*q*,) the vulva (*m*,) and the urinary organs (*n*.) Two anterior small sympathetic ganglia, which receive nerves

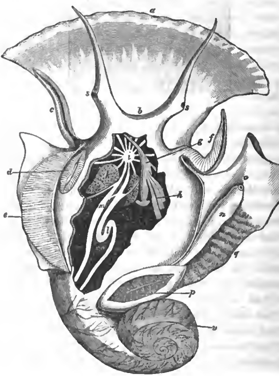
FIG. 91.



from the lateral ganglia (*f*,*f*,) of the brain (*e*, *e*,) are perceived in this animal near the cardiac orifice of the strong, dense muscular gizzard. So that, although the *bulla* is almost acephalous, it has attained a considerable development both of its symmetrical and sympathetic systems of nerves. Instead of a simple nervous band passing over the œsophagus to connect the lateral ganglia, as in the *bulla*, there are two pairs of ganglia around that passage in the *janthina*, and in the *limnea ;* the ganglia are approximated to form a collar around the œsophagus. In the *doris*, the *testacella*, and many others, these ganglia are confined to a supra-œsophageal position, extending as a broad lobed nervous mass across the upper part of that canal. In the *chitons* there is a broad supra-œsophageal band and two closely approximated lateral ganglia below the œsophagus which send back large nerves to the foot and sympathetic filaments to the abdominal viscera.

The *vermetus* has, like the *aplysia*, a small anterior infra-œsophageal ganglion besides the ordinary supra-œsophageal and two lateral ganglia; the infra-œsophageal ganglion is situate beneath the muscular bulb of the œsophagus, and a small sympathetic ganglion, placed near the stomach, receives filaments from the lateral ganglia, and sends nerves to the abdominal viscera. In the long body of the *dentalium* the brain forms a single lengthened quadrilateral ganglion extended longitudinally above the œsophagus, and sending down small nerves on each side to complete the œsophageal ring. In the pulmonated gasteropods the brain is generally more equally divided between the upper and lower surfaces of the œsophageal ring, the broad ganglia in these two situations having a bilobate form. The highest forms of the pectinibranchiate gasteropods, as the *buccinum* and the *harpa*,

FIG. 92.



have the greatest portion of the ganglionic matter of the œsophageal nervous ring accumulated in a cerebral position above the entrance of the alimentary canal, as seen in the annexed figure of the *harpa elongata* (Fig. 92,) from New Guinea, where the mantle (*o*,) is opened to show the branchiæ (*d*, *e*,) and the syphon (*c*,) on the left, and the mucous follicles the colon (*n*.) and the male organ (*f*.) on the right side of the respiratory cavity. On opening the anterior part of the trunk the retracted proboscis (*g*) with its muscles (*h*.) are seen extending backwards over the brain (*i*.) which rests on the inferior turn of the œsophagus where the two salivary glands (*k*. *k*.) are also placed. From this cerebral mass (*i*.) large nerves are seen extending forwards to the head (*b*,) the tentacula, with the eyes (*s*. *s*,) at their base, and to the broad fin-like anterior fold (*a*,) of this long tapering inoperculate foot. Other nervous chords extend downwards to the ventral surface of the abdomen, and backwards to the sympathetics which supply the abdominal viscera. This gradual concentration of the ganglionic matter of the great œsophageal nervous ring of the gasteropods into a cephalic position and form, on the median plain above the alimentary canal, is a preliminary to its enclosure in a distinct cranial covering, which takes place in the cephalopods.

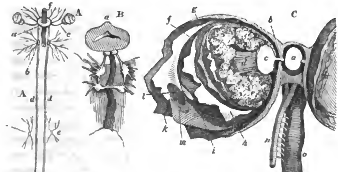
The nervous system of the *pteropods* presents the same general plan and the same varieties of form in its cephalic masses as seen in the gasteropods, especially in the naked and swimming species. In the *clio borealis* (Fig. 93, B.) one of the small naked swimming pteropods, there is a double nervous collar around the œsophagus, as in the aplysia and many other gasteropods. Two small ganglia approximated to each other to form a bilobate brain are placed above the œsophagus immediately behind the lips (93, B *a*,) and indicate by their diminutive size the imperfect development of the organs of the senses in this animal which scarcely presents a trace either of eyes or tentacula. Behind these central ganglia are two larger lateral ganglia connected together by a transverse band below the œsophagus, and which supply the principal nerves to the muscular closed mantle enveloping the trunk. Two nervous bands proceed from

each of this middle pair of ganglia, one of which connects them with the cerebral, and another proceeding backwards connects them with a posterior pair of ganglia, which are united by a transverse chord above the œsophagus. The ganglionic portion of this cerebral ring, or perforated brain, is more developed below than above the œsophagus in the *pneumodermon*, where there is only a narrow transverse band above that passage, and three pairs of ganglia disposed symmetrically below. Four of these inferior ganglia are almost in contact on the median plain, and two are more lateral and separate. But in the *hyalea* the nervous matter is chiefly concentrated into a large supra-œsophageal broad ganglion of a quadrangular form, which gives off branches from its four angles. Two of these nerves passing round the œsophagus enter a double ganglion placed below that passage.

The nearest approach to the vertebrated form of the nervous sytem is that presented by the *cephalopods*, the highest of the mollusca and of all the invertebrata. The œsophagus still perforates the brain, as in all the inferior classes, but the greatest portion of that organ and the symmetrical columns prolonged from it are here placed above the alimentary canal. The brain is enclosed in a distinct organized cranial cavity, numerous symmetrical ganglia are developed on the great nervous axis both before and behind that organ, and sympathetic ganglia are observed in the abdominal cavity. The supra-œsophageal portion of the brain in the *nautilus* forms a thick transversely-elongated band, imperfectly surrounded by the cranial cartilage, and enclosed in a tough membrane, as in many of the gasteropods. It is extended laterally into the small optic ganglia of this animal, and is connected laterally with an anterior and a posterior sub-œsophageal ganglionic ring, as in many of the inferior mollusca. Each of the sub-œsophageal bands exhibits two lateral ganglionic enlargements from which numerous branches are ramified forwards and backwards, and the two columns are prolonged backwards from the lateral parts of the brain to the palleal ganglia, as in other cephalopods. In the *loligopsis* (Fig. 93. A.) the brain is enlarged both above and below the œsophagus, and its

superior portion, which forms an oval encephalic mass, is more completely surrounded with a cartilaginous cranium. From the lateral parts of this encephalic ring (*a*,) come off the optic nerves, and the two large longitudinal symmetrical columns (*a. b. d.*) which run parallel and near to each other along the dorsal surface of the abdominal cavity to the caudal extremity of the sac, having the palleal ganglia (b,) in their course. The cerebral ganglion of the *octopus*, (Fig. 93 C. *a*,) forms a more globular concentrated

FIG. 93, C. *a*.

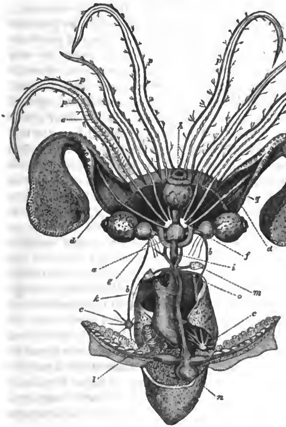


mass enclosed in a thick cartilaginous cranium, covered with a gelatinous cellular arachnoid and a dura mater giving off laterally optic nerves (C. *b*.) to very large optic ganglia (C.*c*) contained within the sclerotic coat of the eyes. The optic ganglia are surrounded with lobed masses of adipose substance (*e. e.*) and send out a large radiated pencil of detached optic filaments (d,) to penetrate the choroid. The brain is separated from the œsophagus (*o*,) and the aorta (*n*,) by the membranous floor of the cranium, the whole periphery of this perforated cerebral mass, encompassing the œsophagus, not being yet surrounded with the consolidated portion of the cranium. On each side of the cranium is a small vestibular cavity occupied by a sac on which the auditory nerve is distributed and containing a limpid fluid, and a calcareous concretion. In the *sepia* the brain is more distinctly bilobate, of a yellowish white colour, and pulpy consistence, smooth on the surface and contained

in a thick cartilaginous cranium, which is perforated for the passage of nerves, and gives attachment externally to the muscles of the head and trunk. The cranium is continued round the œsophagus though soft on its interior part. Immediately anterior to the brain and the cranium is a large heart-shaped supra-œsophageal ganglion, of a yellowish colour, resting over the œsophagus, and sending forwards numerous large nerves to the labial apparatus enveloping the mandibles. On the lower part of the muscular bulb of the mouth, are two small lateral ganglia, which send in numerous large branches to the strong muscles of the mandibles. Both the labial and the mandibular ganglia are connected with the brain by distinct nervous chords. Below the œsophagus, and anterior to the cranium, are two large lateral pedal ganglia, which send forwards large nervous trunks to pass ramifying through the tubular axis of all the feet. These two pedal ganglia are likewise connected by nervous chords with the sides of the brain. The two optic nerves pass through the cranium, from the superior or dorsal lobes of the brain, and enter two large crescentic optic ganglia within the sclerotic, as in other naked cephalopods. The two great longitudinal nervous columns are extended backwards from the sides of the brain, separate from each other, and along the dorsal aspect of the trunk, above the abdominal cavity to the large palleal ganglia which distribute radiating nervous chords chiefly to the interior muscular parts of the mantle. The inner portion of each of these two symmetrical columns (Fig. 93. A. *b. d.*) extending from the brain, along the dorsal region of the cephalopods, does not enter the palleal ganglion, but passing along the inner margin of that ganglion, it penetrates the substance of the mantle by a distinct foramen, and radiates into numerous ramifying chords, which are distributed chiefly on the exterior parts of the trunk. The principal branches of these exterior palleal nerves extend backwards in the direction of the broad thin cartilaginous laminæ which support the branchial muscles, and two filaments extend inwards to the abdominal sympathetic ganglia (93. A. *e. e.*) placed at the base of the branchiæ, near the lateral hearts. By means of the two sub-œsophageal pedal ganglia anterior to the

brain, a second nervous ring is formed around the œsophagus in the cephalopods, as in most of the gasteropods and pteropods. On opening the skull of the *argonauta* from behind, as in the annexed figure (Fig. 94,) by Chiaje, the brain (*a*,) of a round form above, separated from the inner parietes

FIG. 94.



of the skull by the gelatinous arachnoid, and extending downwards to encompass the œsophagus (*i*,) is observed to give off laterally the large optic nerves (*g*,) which perforate the cranium to reach the pedunculated eyes, and from its more anterior portion the separate great symmetrical columns (94. *b*, *b*,) which extend backwards to the palleal ganglia (94.

c, c,) on each side of the crop (*k,*) the aorta (*n, o,*) and the salivary glands (*m,*) and above the branchiæ, and the genital organs. By removing the anterior supra-œsophageal heart-shaped labial ganglion, and the œsophagus, the great lateral sub-œsophageal pedal ganglia (*f,*) are perceived to send forward large nervous trunks (*d, d, d, e, e,*) which extend ramifying through the central canal of each arm along with the blood-vessels. A separate nervous tract, like that seen in the dorsal columns of the cephalopods, is seen to pass backwards along the sides of the supra-œsophageal ganglion of the *buccinum* and other gasteropods, and having the same pellucid appearance as the simple ungangliated nerves of most invertebrata ; the same tract of simple nerves is seen in the symmetrical columns of conchiferous mollusca especially, as in the cephalopods, at the great posterior pair of symmetrical ganglia. The dorsal columns prolonged from the brain are more approximated, parallel, and lengthened in the *loligopsis* and *loligo* than in most of the naked cephalopods, which corresponds with the lengthened and narrow form of the trunk in these animals. The great nervous trunks, (94. *d, d, d,*) proceeding from the inferior ganglia (*f,f,*) anterior to the brain, and accompanying the artery and vein (*p,p,p, q,q,q,*) through the axis of each arm, send out lateral ramifying branches at regular, short, and decreasing distances from both sides, corresponding with the position of the exterior suckers, and these nervous trunks, diminishing in size as they advance towards the apex of the arm, present throughout their whole course a beaded or knotted appearance, like the nervous axis of a worm. In the long cylindrical trunk of the *loligo* the nervous columns are continued from the two palleal ganglia, along the whole extent of the dorsal surface of the body, and send out numerous lateral branches to the caudal fins, which are seen radiating and ramifying to their extreme margins. As the great trunks of the sympathetic in the inverted bodies of the articulated animals occupy the dorsal region of the abdominal cavity, and the symmetrical columns the ventral, we find that in the cephalopods where the columns extend along the back, as in the higher classes of vertebrata, the branches of the great sympathetic proceeding from the inferior surface of the brain, extend along the ventral aspect of the abdomen, between the liver

and the ink-gland to the bottom of that cavity, where they form a ganglion which sends nerves to the digestive, the circulating, and the respiratory organs. So that, although the brain of the cephalopods is still perforated by the œsophagus, as in all the inferior classes, we find all the principal parts of the nervous system of the vertebrata already developed in this class, and after undergoing a series of changes of form and position in the inferior tribes of animals, regulated by the general development and form of the body, they have here acquired the form and situation which they preserve throughout all the higher classes to man. This system begins the development of its ganglionic axis in the lowest acephalous mollusca, as in the lowest helminthoid articulata, below the œsophagus, and extends along the ventral surface of the abdomen; but in the higher gasteropods, as in the highest insects and crustacea, we find it advanced in its position, accumulated around the entrance of the digestive canal, and mounting to a dorsal position, which nearly the whole of the lengthened spino-cerebral axis has attained in the cephalopods.

FIFTH SECTION.

Nervous System of the Spini-cerebrated or Vertebrated Classes.

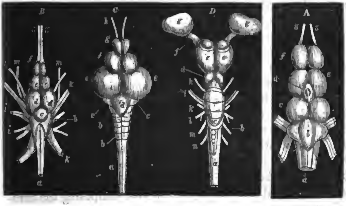
The great axis of the nervous system occupies entirely a dorsal position in the vertebrated classes: it is enclosed in an osseous sheath, which is continued over its posterior prolongation, and it is no where perforated by the alimentary canal. The fibrous structure of the encephalic portion which is perceptible in the cephalopods, becomes more distinct and obvious as we ascend through the vertebrated classes; and that anterior part of the nervous axis becomes likewise proportionally larger, leaving only slight traces, in the fourth ventricle, of its original opening for the passage of the alimentary canal. The spinal chord, the medulla oblongata, the optic lobes,

and the cerebral and cerebellic hemispheres, form the most constant elements of this axis, but their relative and actual developments vary in the different classes. They are composed of minute neurilematous tubular filaments which form two posterior contiguous sensitive or ganglionic columns and two anterior motor columns, the filaments and nerves of which are not interrupted by ganglionic enlargements. Though much varied in the extent of its development in the different classes, there is great similarity in the successive stages of the development of this system in the embryos of all the vertebrated animals and great uniformity of plan in all its adult forms. Beginning with the two columns of the axis, like the two chords of a worm, it becomes reinforced by filaments from every part of the periphery, and gradually receives its ganglionic enlargements, as in all the inferior tribes, where they are most required by the developing organs of the body. The great sympathetic, or nervous system of *organic life*, which is extended along the upper or dorsal side of the symmetrical axis in the inverted bodies of the articulata is here developed along the ventral or under surface of the spino-cerebral axis, and like the sympathetic system of the highest entomoid classes it is enclosed with the viscera, in a cavity distinct from that which envelopes the nervous axis of *animal life*.

In the long vermiform bodies of the lowest cyclostome fishes, as the *lamprey*, the *pride*, and the *gastrobranchus*, the two slender columns extended along the back and scarcely protected by a cartilaginous sheath, are nearly without cerebellum, and destitute of ganglionic enlargements in their course to the head, where the minute cerebral elements are enclosed, like the ganglia of a cephalopod, in a cartilaginous tube, consisting of a single piece. This simple condition of the axis presented by the lowest fishes, resembles the primitive embryo-state of this system in the highest vertebrata before the extremities begin to shoot from the sides of the trunk. In fishes, as in cephalopods, where a large exterior surface of the skull is required for muscular attachments, the minute brain does not fill the cavity of the cranium, and the space between the *dura mater* which lines the skull and the *pia mater*

which invests the cerebral organs is occupied by the soft transparent semifluid cellular tissue of the arachnoid coat which passes down likewise through the vertebral canal, enveloping the spinal chord. The spinal chord is nearly equal in its development throughout the vertebral column, even in many of the anguilliform osseous fishes, from the smallness of the arms and legs not requiring those enlargements which we observe in most higher animals, where the nerves of larger and more powerful extremities are given off. In species which have the arms of great magnitude, as rays and flying-fishes, there is a proportionate development of the upper enlargements of the spinal chord. The number and the extent of these enlargements of the spinal chord in fishes corresponds with that of the members developed from the periphery of the trunk. In the *trigla* (Fig. 95. C,) where the pectoral fins are of great size, a series of ganglionic enlargements (95. C. *b. b*,)

Fig. 95.



of the spinal chord (*a*) are observed at its upper part, which corresponds in number with the number of the large detached rays of the pectoral fins presented by the different species, *trigla cuculus* having five enlargements and five detached rays, and the *trigla lyra* (95, C.)

having six of each. The posterior extremity of the chord is sometimes sensibly enlarged where nerves proceed to the muscles of a large caudal fin, and in abdominal fishes an enlargement is observed, corresponding with the ventral fins. In some fishes with a great development of the head and anterior portion of the trunk, as the *frog-fish*, and the *tetrodon*, the spinal chord passes but a short way through the vertebral canal, and a long *cauda equina* extends backwards, as in the human body. The symmetrical nerves arise by double roots from the two grooves on each side of the spinal chord, the motor nerves which commence more towards the tail than the sensitive, originate from the anterior lateral groove, and the sensitive nerves, provided each with a ganglion beyond the vertebral canal, originate from the posterior groove. These unite, as in the invertebrated classes, to form mixed, moto-sensitive nerves, they give sensibility and motility to the organs of animal life, and they send filaments to the sympathetics—each vertebra being analogous to a segment of the trunk, and each pair of symmetrical nerves originating from the brain of that segment. The nervous œsophageal ring of the invertebrata is still perceptible in the wide opening between the lateral halves of the medulla oblongata of the lampreys. The great fasciculi composing the cerebral masses the *corpora pyramidalia*, *olivaria* and *restiformia* are already obvious in the large medulla oblongata of fishes ; but the crossing fasciculi of the *corpora pyramidalia* are slightly marked, they become apparent and numerous as we ascend through higher classes. The *medulla oblongata*, the apparent origin of most of the cranial nerves, is here large and lobed, and often nearly as broad as the cerebral organs before it in the cranium ; it is deeply marked above by a *calamus scriptorius*, at the bottom of the fourth ventricle, which is situate between it and the single median lobe composing the cerebellum.

Anterior to the medulla oblongata and cerebellum, there are generally in osseous fishes three pairs of rounded lobes placed in front of each other along the floor of the cranium, and occupying but a small portion of that capacious cavity, as seen in the brain of the *conger-eel*, *murœna conger*

(Fig. 95. A,) where these three pairs of lobes are nearly equally developed and similar in form. The posterior pair, (95. A. *c*,) immediately before the cerebellum (95. A. *b*,) are the *optic lobes* or corpora quadrigemina, which are hollow internally, as in the human fœtus, and give origin to the principal fibres of the optic nerves. The second or middle pair of lobes (95. A. *e*,) are the *cerebral hemispheres*, which are here, as in the human embryo, destitute of internal ventricles and without external convolutions. The anterior pair (95. A. *f*,) are the *olfactory tubercles*, which are entirely appropriated to the olfactory nerves (95. A. *g*, *g*.) In the *trigla lyra*, (Fig. 95. C,) where the medulla oblongata (*b*, *b*,) is marked by ganglionic enlargements, and the cerebellum (*d*,) is proportionally small, the optic lobes (*e*, *e*,) are much larger than the cerebral hemispheres (*f*,) and the olfactory tubercles (*g*,) are much inferior in size. In the *perch*, (Fig. 95. B,) the medulla oblongata (*a*,) forms two broad lobes at its anterior termination (*b*,) over which the elevated cerebellum (*c*,) arches backwards. The optic lobes (95. B. *d*, *d*,) have an elongated form, the cerebral hemispheres (*e*, *e*,) much smaller than the optic lobes, are extended vertically, and the olfactory tubercles (*f*,) form two slight spherical enlargements at the commencement of the olfactory nerves (*g*, *g*.)

In most fishes, as in the earliest condition of the human brain, the *optic lobes* are larger than the hemispheres; they are smooth and cineritious on the outer surface, and destitute of the transverse sulcus which gives them a quadrigeminous appearance in the adult mammalia; they are hollow within and have their inner parietes lined with white medullary fibres. The ventricles of the optic lobes communicate freely with each other, and they open behind, by a narrow aquiduct, into the fourth ventricle beneath the cerebellum. The interior white medully parietes of these two lateral cavities meet above on the median line, and form an extended commissure like the corpus callosum of the hemispheres; they descend along the median line to form a prominent ridge, but not a complete septum, between the ventricles. The optic lobes of fishes, like their medulla oblongata, are larger in proportion to the cerebral hemispheres than in any of the higher vertebrata, and they present the same great proportions the earlier we observe them in the human embryo. Their development

corresponds generally with that of the *corpora olivaria*, the optic nerves, and the eyes, but is in the inverse ratio to that of the cerebral and cerebellic hemispheres. The inner medullary fibres of the optic lobes pass transversely and arch upwards over the contained ventricles, but the exterior fasciculi advance longitudinally to the optic nerves. The cineritious portion predominates in these and other parts of the brain, as in the human embryo; and the wide canal extending through the middle of the spinal chord of fishes corresponds also with the fœtal condition of that part in mammalia. These optic lobes, the first formed portions of the brain anterior to the medulla oblongata, being analogous to the supra-œsophageal ganglia which give origin to the optic nerves in the invertebrata, are almost alone developed in the cyclostome fishes; they are large compared with the cerebral hemispheres in most of the osseous fishes (95. C,) they are comparatively small in the anguilliform fishes (95. A,) their size is much reduced in the plagiostome chondropterygii (95. D. *d*,) and they become proportionally smaller as we ascend through the higher classes to man. They contain within their cavity one or two pairs of tubercles and the large corpora candicantia lie beneath them on the inferior surface of the brain. The anterior and posterior commissures are already developed, and also a rudimentary fornix.

Anterior to the hollow optic lobes of fishes are the proper *cerebral hemispheres*, (95. A. *e*,) which are scarcely perceptible in the cyclostome fishes, are very small in most of the osseous fishes, (95. B. *e*, *e*,—C. *e*, *e*,) equal the optic lobes in the apodal fishes (95. A. *e*,) and have attained in the plagiostome species (95. D. *e*, *e*,) a much greater size than these small optic lobes, (95. D, *d*.) In the osseous fishes, as in the embryo condition of the human hemispheres, they are destitute of internal ventricles, smooth and cineritious on the surface, without external convolutions, and they are composed internally of radiating white fasciculi derived from the corpora pyramidalia. In the rays and sharks (95. D. *e*, *e*,) where the hemispheres attain a great size, they already present inequalities on the surface, they begin to extend backwards over the small optic lobes, (95. D. *d*,) and they already manifest distinct ventricles in their interior, which continue in almost all the higher animals to man. The cerebral or

lateral ventricles are continuous with the canals of the olfactory nerves (95. D. *f*,) as in all the higher classes. These cerebral lobes, perhaps the analogues of the thalamic optici, are developed in the direct ratio of the corpora pyramidalia and crura cerebri, and their increased development in higher animals corresponds also with the enlargement of the lateral lobes or hemispheres of the cerebellum.

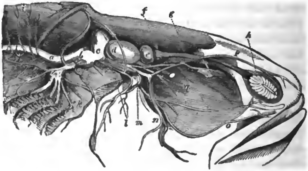
Before the cerebral hemispheres are placed the most anterior pair of lobes, which here, as in higher classes, are appropriated to the olfactory nerves, and vary in their form, size, and situation more than any of the other parts of the brain. These *olfactory tubercles* are generally in the osseous fishes, (95. B. *f*, C. *g*,) in immediate contact with the cerebral hemispheres, and inferior to them in size ; in the anguilliform fishes (95. A. *f*,) they nearly equal the hemispheres (95. A. *e*,) and in the plagiostome fishes (95. D. *g*,*g*,) they are placed on the course of the olfactory nerves at a greater or less distance from the hemispheres (95. D. *e*, *e*,) and present a great transverse development, exceeding in magnitude the hemispheres themselves. In these last fishes the rays and sharks, the large cineritious olfactory lobes are situated at the end of thick peduncles and lie immediately above the cribriform plate of the ethmoid which the olfactory nerves perforate to be distributed on the extensive pituitary membrane covering the laminæ of the nose.

The *cerebellum* forms only a minute transverse band on the median plain in the cyclostome fishes, where it can be perceived, and in the higher osseous fishes (95. B. *c*,) it still consists merely of a simple median lobe, smooth on the surface, destitute of lateral hemispheres, and analogous to the vermiform median lobe first developed in the cerebellum of the human embryo. It rises vertically in the osseous fishes (Fig. 96. *c*,) compressed between the optic lobes (96, *d*,) and the lobes of the medulla oblongata (96. *b*,) and generally extends backwards, tongue-shaped, over the fourth ventricle, but is destitute of the laminated surface which it begins to present in the plagiostome fishes. This median portion of the cerebellum, (95. D. *c*,) like the cerebral hemispheres, (*e*, *e*,) is greatly developed in the muscular rays and sharks, extending backwards over the medulla oblongata and forwards over the small optic lobes (95. D. *d*,) and already presents not only a

transversely laminated structure, as in higher classes, but also small hemispheres extending laterally like tubercles from its base. Its magnitude here corresponds, as in higher classes, with that of the corpora restiformia, which are conspicuous in the plagiostome fishes, and it presents internally an arborescent appearance of white diverging fasciculi, arising from its laminated structure.

All these lobes contained within the capacious cranium of fishes are covered with cineritious substance, and derive their internal white fibrous parts distinctly from the great fasciculi of the medulla oblongata, the corpora pyramidalia, olivaria, and restiformia. From the great size of the olfactory and the optic nerves in this class, as seen in the perch, (Fig. 96.

FIG. 96.



g, *q*,) and also of the fifth pair (96. *m*,) and from the smallness of the three pairs of lobes from which these nerves originate, the cerebral hemispheres (*e*,) the optic lobes (*d*,) and the medulla oblongata (*b*,) appear only like small ganglia appropriated to these nerves. The olfactory tubercles (96. *f*,) are generally contiguous to each other and to the hemispheres, and the white fibres of the olfactory nerves (96. *g*,) pass forwards on their lower surface from the cerebral lobes (96. *e*.) Two commissures are generally perceptible in the cerebral lobes, and beneath the small lobules in the optic lobes a third ventricle is seen leading downwards to the in-

fundibulum and the large petuitary gland. The pineal gland (95. A. *d*,) with its small peduncles, is seen between the optic lobes and the hemispheres, as in higher classes, and is composed chiefly of cineritious substance.

From the great extent of the cranial cavity and the smallness of the brain, the cerebral nerves have a long free course from their origin to their cranial foramina. In the osseous fishes the optic nerves (96. *q*,) generally cross each other without uniting or intermingling their fibres, but in the plagiostome fishes they unite and decussate, as in mammalia. From the great size of the organs of vision in this class, and of the muscles which move them, not only the optic nerves are proportionally large, but also the third, fourth and sixth pairs, or oculomotory, trochlear and abducent nerves, which are the motor filaments of these muscles. The abducent nerves advance forwards from the inferior surface of the medulla oblongata, where they arise between the posterior fibres of the large trigemini. This large fifth pair (Fig. 96. *m*,) arising from the sides of the lobes of the medulla oblongata immediately beneath the cerebellum (96. *c*,) gives off the ophthalmic (96. *p*,) which passes forwards through the orbit above the eye to be distributed on the upper part of the face ;—the superior maxillary (96. *o*,) which passes under the eye to ramify on the sides of the face ;—and the inferior maxillary (96. *n*,) which supplies chiefly the palate and lower jaw. The principal branches of the seventh or facial nerve (96. *l*,) are distributed on the posterior part of the face and neck. The great pneumo-gastric nerves (96. *k*,) arising behind the trigemini, from the sides of the medulla oblongata present a large ganglion, from which branches pass downwards to the branchiæ, and backwards along the œsophagus to the stomach, and air sac or rudimentary lungs ; and before these is a branch analagous to the glosso-pharyngeal, which supplies the tongue and anterior branchial arch. This great ganglion of the pneumo-gastric (96. *k*,) is sometimes close to the origin of the nerve, and sometimes remote ; and a branch from this nerve, like the accessary of Willis, extending longitudinally on the side of the whole body near the lateral line sends filaments to the surface. The pneumo-gastric supplies nerves also to the electrical organs of the *torpedo*. The acoustic nerve, arising between the trigeminus and the great

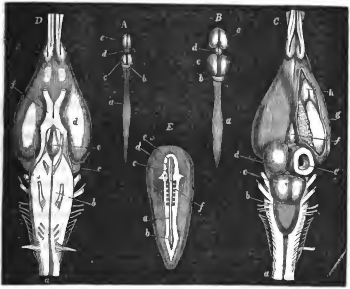
pneumo-gastric, descends to the vestibule and long semi-circular canals.

The spinal nerves, like those of the cranium, have generally a long course before they pass out through the intervertebral foramina, and the ganglia of their posterior roots are often so small, especially in osseous fishes, as to be scarcely perceptible, and slight enlargements of the spinal chord can sometimes be distinguished at the origins of the several pairs of symmetrical nerves. The great sympathetic arising from cranial nerves as high as the trigeminus, is reinforced in its course backwards by branches from the spinal nerves, and forms plexuses and ganglia, as in higher classes, before being distributed on the organs of the trunk; it is more distinct in the plagiostome chondropterygii than in the osseous fishes, and is least developed in the cyclostome species. It forms small ganglia along the sides of the vertebral column, where it receives filaments from the spinal nerves, and its plexuses embrace the arterial trunks before ramifying on the digestive, respiratory, and generative organs.

In the perennibranchiate *amphibia*, and in the larva state of those which lose the gills, the spinal chord, the medulla oblongata, and the cerebral parts contained within the cranium present the same proportions and general conditions which we observe as permanent characters in most of the osseous fishes; but the cerebellum is generally smaller in amphibia and reptiles than in all the other vertebrata. As in the lower fishes, the spinal chord in these inferior forms of amphibia is prolonged, small and tapering, through the greater part of the coccygeal vertebræ, without distinct enlargements where the nerves usually come off to the arms and to the legs. The medulla oblongata is yet broad and lobed, the cerebellum in form of a very small median transverse lobe without hemispheres, the optic lobes large, cineritious, smooth without, hollow within, and quite exposed, and the cerebral hemispheres, extended longitudinally, smooth and cineritious externally, without internal ventricles, and smaller than the optic lobes. The metamorphosis of the caducibranchiate species changes the condition of their nervous system from that of the lower fishes to nearly that of the reptiles above them; and these changes are effected so rapidly that we can perceive a marked advancement in the

development of the nervous system of the tadpole produced in one day. In the tadpole of the common frog, on the fourth day, (Fig. 97. A.) the spinal chord is perceptibly en-

FIG. 97.



larged at its posterior part (*a*,) and also the medulla oblongata. The cerebellum (*b*,) is scarcely visible, extended across the median plain ; the optic lobes (*c*,) and the cerebral hemispheres (*e*,) are small, narrow, and so far separate longitudinally as to expose entirely the intervening optic thalami (*d*.) On the following or fifth day (Fig. 97. B,) besides the general encrease of the spinal chord (B. *a*,) the cerebellum (B. *b*,) is perceptibly enlarged, the optic lobes (B. *c*,) are proportionately broader and shorter, and the cerebral hemispheres (B. *e*,) encreased in every direction, begin to extend backwards over the optic thalami (B. *d*.) As the tadpole advances in its development, and the legs and arms are extended from the sides, the posterior and middle enlargements of the spinal chord are proportionately encreased, the cerebral hemispheres enlarge, and their white fibrous internal

parts predominate over the cineritious covering, but they present no convolutions nor ventricles. By the rapid growth of the dorsal vertebræ, and the obliteration, anchylosis, and absorption of the coccygeal vertebræ, the spinal chord appears to recede from behind forwards, within the vertebral canal and the cauda equina to lengthen. The anterior extremity of the chord is enlarged from the first, as it gives origin to most of the cranial nerves, and the posterior end is enlarged for the cauda equina, as is even perceptible in fishes and serpents. Here, as in other classes, where the spinal chord by the progress of development, is retracted within its osseous sheath, and the cauda equina is thus lengthened in the adult state, there is a greater distance observed between the origins and the places of junction of the motor and sensitive roots of the nerves which compose it, and consequently between the intevertebral ganglia and the spinal chord ; and this is most manifest at the posterior end of the column, which has been most influenced by the metamorphosis. The long narrow cerebral hemispheres of the adult frogs taper to the olfactory nerves which commence with cineritious tubercles, and the optic nerves are observed distinctly to cross each other before the optic tubercles. The changes effected in the nervous system by the metamorphosis of the higher amphibia closely resemble those produced by development in the human embryo. Their sympathetic nerves and ganglia are more distinct than in fishes.

In the class of *reptiles* the small cavity of the cranium nearly corresponds with the dimensions of the enclosed brain, as in some fishes, and the superficial cineritious substance still predominates over the internal white fibrous matter, though to a less extent than in fishes and amphibia. The cerebellum is remarkable for its proportionate smallness in this class, and the cerebral hemispheres, containing each a distinct ventricle, now always exceed the optic lobes. The spinal chord of serpents, from their want of arms and legs, is still destitute of enlargements, as in the apodal fishes, but the medulla oblongata is of considerable size, and the fourth ventricle, still uncovered by the small cerebellum, descends into the spinal chord. From the smallness of the brain and cranial cavity in the centre of the head of reptiles, the rela-

tive size of these parts does not influence that of the whole head at different periods of life, and the head preserves the same proportions to the rest of the body through life also in amphibia and fishes. From the still imperfect development of the cerebral parts in this class, the vital functions of reptiles are less immediately dependent on them than in hot-blooded animals, and they longer survive their mutilation. In the saurian and chelonian reptiles the posterior and middle enlargements are obvious on the spinal chord at the origins of the nerves of the extremities. The wide medulla oblongata within the cranium is marked longitudinally by the limits of its three component fasciculi on each side, and the decussating bands of its corpora pyramidalia are more distinct than in fishes. The nerves of the body bear a large proportion to the size of the cerebral centres, and correspond in their distribution to those of the higher air-breathing classes. The great ganglia and plexuses of the sympathetics now more closely accompany the arterial trunks, as we see to become more exclusively their distribution from the articulated and the molluscous classes up to man. The twelve pairs of cranial nerves are seen here as in birds and mammalia, and they chiefly arise from the enlarged medulla oblongata, as seen in the annexed figures of the brain of the tortoise, *emys europœa*, Fig. 97. C. D. Immediately before the anterior roots of the first cervical nerves (97. D. *a*,) are seen on the inferior surface of the medulla oblongata, the origins of the *hypo-glossal*, or twelfth pair of cranial nerves, and on the sides, the numerous branches of the *spinal-accessory*, or eleventh pair. Before these are seen on the sides, two portions of the *pneumo-gastrics* and the *glosso-pharyngeal*, or ninth pair. Close together are the *acoustic* and the *facial nerves*, and towards the median plain below are the sixth pair, or *abducentes oculorum*, (97. D. *b*.) The small *motores oculorum* are seen anterior to these last, and on the sides the large trunk of the *trigeminus*. The short and broad cerebellum (97. C. *c*,) not extending backwards to cover the fourth ventricle, that cavity is found protected externally by a highly vascular membrane (97. C. *b*.) The small transversely developed cerebellum consists only of the median lobe, without hemispheres, and consequently still is without the corpus dentatum in its interior; it is smooth and cineri-

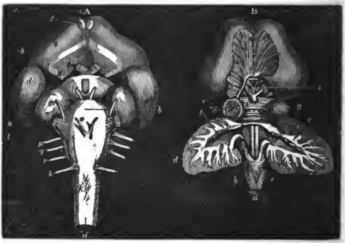
tious without, and presents internally radiating fasciculi of white nervous fibres extending peripherad from its base. The great transverse commissure of the cerebellum, or the pons Varolii is still wanting, like the cerebellic hemispheres. The optic lobes (97. C. *d*, *e*,) reduced in their proportions, and provided with internal ventricles (*e*,) are partially encompassed on their fore part by the large tapering hemispheres. The cerebral hemispheres (97. D. *d*,) destitute of convolutions, smooth and cineritious externally, hollow within, (97. C. *g*,) present internally the thalami optici and corpora striata (*g*,) and a distinct choroid plexus, (97. C. *h*,) towards the median side of their contained ventricles. These hemispheres are broad and short in the crocodilian reptiles, and more lengthened, narrow, and tapering forwards in the inferior tribes, especially in the chelonia. Rudiments of cerebellic hemispheres are also seen in the crocodiles. The olfactory tubercles (97. D. *g*,) are much smaller than in fishes, cineritious externally, and placed in contact with the cerebral hemispheres. On the inferior surface of the brain in the chelonia (97. D,) we observe an intimate union and decussation of the optic nerves (97. D. *f*,) and behind these a long tubular hypophysis (97. D. *e*,) or continuation of the third ventricle into the infundibullum and petuitary gland. The pineal gland (97. C. *f*,) is still exposed on the upper part of the brain between the optic lobes and the cerebral hemispheres. All the parts of the brain are more compacted together in reptiles than in lower vertebrata; the ganglia of the posterior or sensitive roots of the spinal nerves are now more conspicuous, like the lateral and splanchnic ganglia of the sympathetics; and the spinal nerves come off more nearly opposite to the places of their respective destinations than in the lower classes.

The nervous system of *birds* presents only a more elevated condition of the same plan of structure already developed in the crocodiles and inferior reptiles. The great centres of the nervous system in the vertebrated animals like those of the vascular, are at first developed in a lineal direction and extended longitudinally, as we see in the fishes, but at length acquiring encreased lateral development, these parts, in both systems become compacted together and accumulate upon each other to form a more short, circumscribed and

rounded mass, more easily accommodated and protected, as we see in birds and mammalia. The spino-cerebral axis fills the osseous cavities which protect it, and the form and size of the upper part of the head now correspond with those of the enclosed brain at every period of life. The spinal chord, become more rounded in form, has an encreased proportion of grey ganglionic matter in its interior, and the white fibrous medullary portion is encreased in the brain. The enlarged cerebral parts being now collected into a more compact form, the hemispheres of the brain extend backwards to cover the optic lobes, and come into contact with the greatly encreased cerebellum. The olfactory tubercles have much diminished, but retain their tubular communication with the still small ventricles of the cerebral hemispheres. The cerebral hemispheres still destitute of convolutions and partially bilobate, and the median lobe of the cerebellum deeply laminated and sulcated transversely, are the parts here most developed in the cranium, and the white fibres of the great cerebral commissure, the corpus callosum, have begun to shoot across and unite the hemispheres. Notwithstanding the great transverse extension of the cerebral mass in adult birds, and its sudden tapering forwards to the olfactory nerves, giving the whole brain a triangular appearance, it presents the same lineal arrangement and longitudinal extension of its parts in the embryo, which are preserved as the permanent character of the nervous axis of fishes. This is easiest observed by examining its development in the transparent area of the cicatricula in the egg of the fowl, where we perceive after two days' incubation (Fig. 97. E,) the two halves of the spinal chord (E. *a*,) united posteriorly, and already forming the vesicular enlargement (97. E. *b*,) corresponding to the cauda equina and pelvic dilatation, or rhomboidal sinus of the adult. The cervical and dorsal vertebræ begin to embrace the anterior portion (97. E. *f*,) of the chord, and three vesicular enlargements are seen on the cephalic portion of the nervous axis. The posterior (97. E. *c*,) of these enlargements forms the rudimentary lobes of the medulla oblongata, the middle dilatation (97. E. *d*,) constitutes the outline of the optic lobes, the anterior (97. E. *e*,) and smallest cephalic enlargement forms the embryo condition of the cerebral hemispheres in the chick, and all these lobes are

still disposed on the same plain, and in a longitudinal direction, as we find them in the adult fishes and in the embryos of mammalia. They incline forwards as they develope upwards and backwards and laterally, and in the adult condition the optic lobes, reduced in their proportion and forced downwards and to the sides, are covered by the expanded cerebral hemispheres, which reach and even partially overspread the cerebellum. The spinal chord still extends into the coccygeal vertebræ, and the decussating bands of the corpora pyramidalia are more numerous and distinct than in the inferior vertebrata, as seen in the medulla oblongata of the *stork*, (Fig, 98. A. *k*.) The cylindrical spinal chord (98. A. *a*,) perforated by a small canal dilates on entering the cranium into

FIG. 98.



a wide and large medulla oblangata (98. A. *b*,) which is not yet traversed by a cerebellic commissure, or pons Varolii. The large cerebellum covers the fourth ventricle, which is extended into it, as seen in the *cassowary*, (Fig. 98. B. *d*, *f*,) it consists of the vermiform or median lobe (98. B. *d*,) and a small rudiment of the lateral lobes or hemispheres (98. A. *l*,) and it is deeply sulcated transversely on the exterior, like the cerebellic hemispheres of mammalia. The numerous me-

dullary bands which radiate outwards to the cineritious exterior lamellæ, from the white fibrous parietes of the fourth ventricle (98. B. *f*,) produce an arborescent appearance when the cerebellum is divided vertically. The ordinary great component fasciculi of the medulla oblongata are distinctly marked externally, and the same nerves arise from this part as in reptiles and mammalia. Where the lateral tubercles or rudimentary hemispheres of the cerebellum are most distinct, a small transverse commissure is already perceptible between them, as in the human embryo, but there is no corpus dentatum.

The optic lobes (98. A. *c*,) reduced in size and separated from each other to the sides of the medulla oblongata by the encreasing cerebrum and cerebellum, are covered externally, like the other lobes of the brain, with cineritious matter, consist internally of white fibres, and present a small ventricle (98. B. *g*,) in each, like the cerebral hemispheres. They are proportionally small and round in the strutheous birds (98. B. *g*, *g*,) more lengthened and oval in the inferior birds (98. A. *c*, *c*,) and present between them transverse medullary bands, (98. B. *k*,) forming a valvular commissure, on which rests the pineal gland (98. B. *i*,) with its two peduncles extending forwards over the thalami optici. The optic thalami covered by the cerebral hemispheres are connected by a cineritious commissura mollis, the optic lobes are without transverse exterior sulci, and the hemispheres are destitute of convolutions though partially divided into two lobes, (98. A. *d*, *e*,) by the fissura sylvii. The cerebral hemispheres, covered externally with cineritious matter, smooth and undulated on the surface, broad posteriorly, and tapering suddenly forwards to the ethmoid bone, cover the thalami optici and the corpora striata, and contain each a small ventricle which extends forwards to the olfactory tubercles (98. A. *f*.) The cerebral hemispheres (98. B. *i*,) are composed chiefly of the ascending and diverging fibres of the corpora pyramidalia and are connected by an anterior commissure, and the crossing fibres of a rudimentary corpus callosum. The olfactory tubercles (98. A. *f*,) commencing from two medullary tracts (98. A. *h*, *h*,) on the inferior surface of the hemispheres, and containing prolongations of the lateral ventricles, are still covered with cineritious substance, and taper forwards to the olfactory nerves, greatly reduced from their proportions in the inferior

vertebrata. The choroid plexus is obvious in each of the lateral ventricles, which communicate below with the third ventricle, and the corpora striata form lengthened transverse eminences. The third ventricle communicates behind with the fourth by the aqueductus Sylvii beneath the transverse valve of Vieussenius, and is continued downwards in front to the infundibulum and petuitary gland which here forms a shorter hypophysis on the sella tursica than in reptiles. All the lobes and cavities are immediately invested and lined by the pia mater, and the dura mater lining the cranium forms a distinct tentorium corebelli and a rudimentary falx cerebri.

The sensitive spinal nerves of birds have their ganglia larger, and approximated more nearly to their origins than in reptiles, and from the retraction and high termination of the spinal chord, as well as the comparative magnitude of the legs in this class, the posterior ganglionic enlargement is remarkable for its size, and at this place the motor and sensitive roots pass out through separate foramina of the numerous anchylosed sacral vertebræ. The twelve pairs of cranial nerves are here distinct as in reptiles and mammalia. The *olfactory* nerves still provided with distinct glandular tubercles (98. A. *f*,) arise from two transverse medullary bands (98. A. *h*,) extending, as in mammalia, to the fissure of Sylvius, and pass forward through the narrow tapering osseous canals formed by the frontal and ethmoid bones. The *optic nerves* (98. A. *i*,) corresponding in magnitude with the large eyes and the optic lobes from which they originate, unite before the hypophysis, and partially decussate their numerous interwoven component fasciculi before proceeding to the optic foramina. The *motores oculorum* pass to the three innermost recti muscles and the inferior obliquus of the eye, the *trochlearis* to the superior obliquus, and the *abducens* to the rectus exterior muscle, as in other classes. The large *trigeminus* sends its ophthalmic branch to the upper parts of the face and nose, the superior maxillary branch to the sides of the face and upper mandible, and the inferior maxillary branch chiefly to the lower jaw; the two last branches exhibit a dental distribution in the serrated mandibles of many aquatic birds, as in the toothed jaws of quadrupeds. The smallness of the facial nerve corresponds with the immobility and insensibility

of the superficial parts of the face, and the magnitude of the acoustic nerve, with the great development of their internal ear and their acute hearing, especially in nocturnal birds. The *glosso-pharyngeal* passes as usual to the tongue and pharynx, the *hypo-glossal* chiefly to the root of the tongue and upper larynx, and the *pneumo-gastric*, communicating at the base of the cranium with the *accessory*, descends with the jugular vein along the neck to be distributed on the lungs, the inferior larynx, the œsophagus and stomach, especially the ventriculus succenturiatus. The spinal nerves are chiefly cervical and sacral, from the number of vertebræ composing these parts of the column, and the brachial and lumbar plexuses are formed and distributed on the arms and legs, nearly as in quadrupeds. The *sympathetic*, greatly encreased in its development, presents distinct lateral ganglia from the base of the skull to the end of the coccyx, it unites anteriorly with the pneumo-gastric, the facial and the trigeminal nerves, and at its posterior end the lateral ganglia become approximated and united on the median plain under the coccygeal vertebræ. It forms distinct ganglia and plexuses around the great arteries, for the viscera of the trunk; its cervical portion is protected, along with the vertebral arteries, in the foramina of the transverse processes; and it is every where connected by anastomosing filaments with the spinal nerves along the sides of the vertebral column, as in other classes.

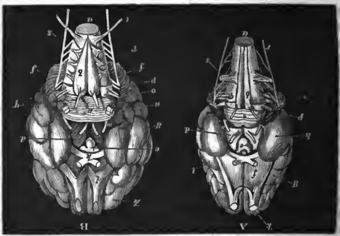
In the *mammiferous* animals a higher grade of the development of this system is perceptible in the magnitude and extension of the spinal chord, and of the cerebral and cerebellic hemispheres, in the encreased number of internal cineritious deposits in all parts of the white fibrous spino-cerebral axis, in the more complete union of all the lateral parts of this axis by means of decussating fasciculi and various commissures of converging fibres, in the encreased size and approximation of the ganglia on all the symmetrical sensitive nerves, and in the more methodical and extensive distribution of the great sympathetic, and its appropriation to individual organs. The spinal chord, though encreased in its proportion to the bulk of the body, is now less in proportion to the cerebral mass than in the inferior classes; its internal longitudinal canal has almost become obliterated; its lateral halves are more intimately united together, and the crescentic

columns of cineritious matter have encreased in their interior. The spinal chord is prolonged to a variable extent through the column, being shortest in the tailless cheiroptera, quadrumana, and man, and longest in the cetacea, where it extends tapering through the coccygeal vertebræ, without posterior enlargement, from the want of legs, as in apodal fishes, and tadpoles, and serpents, and the human embryo. In the long-tailed quadrupeds the spinal chord is extended to the sacrum, and the detached nerves of the cauda equina are prolonged through the coccygeal vertebræ. The ganglionic enlargement of the spinal chord at the origin of each pair of moto-sensitive nerves is now scarcely apparent, and the enlargements corresponding to the atlantal and sacral extremities are of a more lengthened and fusiform shape. The medulla oblongata is comparatively narrow, but it is more deeply marked by the limits of the corpora pyramidalia, olivaria, and restiformia. The decussations of the corpora pyramidalia are more numerous and distinct, and the cineritious matter of the corpus dentatum is generally perceptible in the corpora olivaria, which are themselves proportionally small. The crura cerebri are traversed below by the great commissure of the cerebellic hemispheres, the tuber annulare, which is more or less provided internally with transverse strata of cineritious matter.

The optic lobes, reduced in size, generally without cavities, and traversed externally by sulci, which give them a quadrigeminous appearance, are largest and most exposed above in the lowest mammalia, as the rodentia and edentata, they are larger in herbivorous than in carnivorous quadrupeds, and are least in bulk, and most concealed in quadrumana and man. The anterior lobes of the corpora quadrigemina are larger than the posterior in herbivorous mammalia, the posterior are the larger in carnivora, and these lobes are nearly equal in the highest orders of this class. The cerebral hemispheres follow a contrary ratio in their development, being smallest and destitute of convolutions in the rodentia, and becoming larger in every dimension and more marked with deep convolutions, as we advance upwards to man. The optic thalami and the corpora striata encrease with the expanding hemispheres, while the olfactory tubercles progressively diminish. The olfactory tubercles

are greater in size, more cineritious externally, and contain wider prolongations of the lateral ventricles in herbivorous than in carnivorous quadrupeds. The lateral ventricles always present the anterior and inferior cornua, the choroid plexus, and the tœnia semicircularis between the thalami and the corpora striata. The great transverse commissure of the cerebral hemispheres, the corpus callosum, is here at its maximum of development, as are also the anterior and posterior commissuræ cerebri and the fornix, and we can always perceive the hippocampus major, the septum lucidum between the lateral ventricles, and the pineal gland with its two peduncles. The cineritious matter is now less abundant on the surface of the brain proportionally to the white fibrous part within, and the external convolutions, which are still wanting on the smooth bird-like brains of the montrema and the rodentia, are very superficial in the cetacea, edentata, ruminantia, and pachyderma. The convolutions penetrate deeper in the large expanded hemispheres of carnivora, quadrumana and man, where we observe also the cerebrum to pass more and more backwards over the cerebellum. The symmetry of the convolutions on the two cerebral hemispheres is most distinct where they are few and deep, as in carnivora and quadrumana, and the laminæ of the cerebellic hemispheres encrease in number and depth as we ascend to man. The brain of herbivorous quadrupeds is thus distinguished by several indications of inferior development from that of carnivorous species, as seen in comparing the brain of the pecari, *Dicotyles torquatus*, (Fig. 99. A,) with that of the lion, *Felis leo*, (Fig. 99. B.) In the herbivora the spinal chord and medulla oblongata (99. A. *a*, *b*,) are larger and broader, compared with the cerebral parts which lie before them, than in the carnivora (99. B. *a*, *b*,) and in the carnivora the corpora pyramidalia (99. B. *b*,) the crura cerebri (99, B. *d*,) the cerebral hemispheres (B. *g*, *h*,) the corpus callosum, the cerebellic hemispheres (B. *f*,*f*,) and the tuber annulare (B. *e*,) are proportionally larger than the corresponding parts in the vegetable-eating quadrupeds (99. A.) The convolutions are more superficial on the narrow and short cerebral hemispheres of the pecari, (99. A. *g*, *h*,) the hollow olfactory tubercles or processus mammillares (99. A. *k*,) communicating by wide canals with the lateral ventricles, are larger; the in-

FIG. 99.



fundibulum (99. A. *c*,) like the hypophysis of a reptile, is more broad and extended; the corpora quadrigemina are larger and less covered by the hemispheres, and the transverse sulcus divides them more posteriorly than in the lion, (99. B.) This transverse sulcus is wanting on the optic lobes of the ornithorhyncus, where they are nearly as smooth and undivided as those of a bird, and its cerebral hemispheres are destitute of convolutions, like those of many rodentia, edentata, and marsupialia. The broad cerebral hemispheres of the lion are surpassed in lateral extension by those of the seals, and these parts in the dolphin surpass those of all the other mammalia by their great breadth and by the number of their superficial convolutions. But in none of these animals are the cerebellic hemispheres entirely covered by the extension backwards of the cerebral, till we ascend to the higher quadrumana, where we find in the *pitheci*, or orangs, almost every other character of the human spino-cerebral axis already distinctly developed, as the hippocampus minor and posterior cornu of the lateral ventricles, the deep cerebral convolutions and numerous cerebellic laminæ, the cineritious substance of the corpora olivaria and the large corpora dentata, or ganglionic nuclei of the cerebellic hemispheres.

While the great nervous centres have thus arrived at their maximum of development in mammalia, most of the cranial nerves, like the spinal chord, when compared to them, are proportionately small. The olfactory nerves and tubercles are largest in the ruminantia and pachyderma (99. A. *k*,) smaller in the carnivora (99. B. *i*,) cheiroptera, and quadrumana, and are scarcely discoverable in several of the cetacea. In the inferior orders and in the large eyed nocturnal quadrupeds the optic nerves are of greater size than in diurnal and higher species, and in the blind subterranean moles not only are the optic nerves extremely minute, but the motores oculorum, the trochleares, and the abducentes can scarcely be detected. The optic nerves in this class unite before the infundibulum, where they form a partial decussation of their component fibres (99. B. *k*,) and the ophthalmic ganglion is always perceptible in the orbit. The second and third branches of the trigeminus have a great external distribution in the long-muzzled, the proboscidian, and the large-lipped quadrupeds, as the cetacea, ruminantia, pachyderma, and carnivora, and their internal dental distribution varies according to the number and magnitude of the teeth and of the perforated fangs which they supply. Their development is also influenced by the presence of horns on the frontal or nasal bones, or of spines or bristles extending from the upper lip, as in aquatic and terrestrial carnivora, or by other circumstances which influence the general form of the head or face; and the same causes influence the development of the facial nerves and their branches, as in the inferior classes of vertebrated animals. The bills of the ornithorhyncus, like those of many aquatic birds, are supplied with large branches of the superior and inferior maxillary nerves, and the pneumo-gastric nerve in this animal is not united to the cervical portion of the sympathetic, as it generally is in the neck of quadrupeds. As the plan of development is most constant and obvious in the great centres of animal and of vegetative life, the spino-cerebral axis and the great sympathetic, it is chiefly in those parts that we observe the highest condition arrived at in the human body. The spinal chord of man (Fig. 100. *b*, *i*,) is smaller compared with the cerebral mass contained within the cranium than in other mammalia, and short from the want of caudal prolongation of the trunk; its posterior and

middle enlargements (100. *c. d*,) are conspicuous, and of a lengthened form from the magnitude and number of the nerves which proceed from them to the sacral and atlantal extremities; the cauda equina, (100. *a, b*,) is of great length from the high and sudden termination of the spinal chord; the motor roots (100. *l, l*,) and anterior columns are smaller than the sensitive, as in other animals, and the ganglia of the posterior or sensitive roots (100. *k*,) of the spinal nerves are here larger than in other mammalia. The medulla oblongata, though comparatively small, has its component fasciculi most deeply marked, and the quantity of internal ganglionic matter in the course forwards of these white fibrous fasciculi, corresponds with their great development in the human cerebral and cerebellic hemispheres, where the convolutions (100. *g*,) and laminæ, (100. *h, i*,) surpass in number and depth those of almost all inferior animals, but where the use or function of any filament has not yet been determined. The great systems of converging fibres which cross the median plain, which form the corpus callosum, the tuber annulare, and the various smaller commissures, and which have appeared to some as continuous with the diverging or

FIG. 100.

ascending fibres from the periphery of the cerebral mass, and as forming the posterior or sensitive columns of the spinal chord by their descent from the brain, are larger than in the lower orders of quadrupeds. The periphery of the whole body is now the most largely supplied with symmetrical nerves of motion and sensation, whose roots are the most imbedded and approximated; the great central columns of these nerves are the most intimately and compactly united to each other in every part of the axis, and in passing from the embryo state to this most complicated condition, the great spino-cerebral axis of man presents successively the various conditions exhibited as adult forms in the lower classes of animals. The great sympathetic also presents its highest condition of development in quadrupeds and man, being here most intimately united with all the spinal and cranial nerves from the caudal extremity of the trunk to the trigemini, or fifth pair of cranial nerves. It forms numerous distinct cineritious ganglia in the head, on both sides of the neck, along the two sides of the vertebral column, and in the three great cavities of the trunk, the thorax, the abdomen, and the pelvis, embracing with its large anastomosing plexuses and ganglia the great arteries proceeding to the viscera, and thus it establishes in the most complicated of animal forms the greatest unity of action and mutual dependence of all the organs of animal and of vegetative life.

CHAPTER FIFTH.

ORGANS OF THE SENSES.

FIRST SECTION.

General Observations on the Organs of the Senses.

The power of locomotion enjoyed by animals, and their mode of nutrition by the conveyance of foreign matter into an internal sac, require them to possess the means of obtaining cognizance of the properties of surrounding objects, that they may direct their motions suitably to their ends, and distinguish what is congenial from what is deliterious to their nature. These means of establishing the most intimate relation between external objects and the internal sentient principle, are the *organs of the senses*, which are instruments placed at the peripheral extremities of certain sensitive nerves, generally those nearest the anterior extremity of the trunk, or around the entrance of the alimentary canal, and which vary in their structure according to the properties of outward matter to which they relate. The organs of the senses are thus necessarily placed in connexion with the external surface of animals, and are not situate upon any of the insensitive motor nerves which merely communicate activity to the muscular fibres, nor upon the great ganglionic or sympathetic system of unsymmetrical nerves by which the organs of vegetative life throughout every point of the body are kept in incessant activity without our consciousness, but

only upon the distal terminations of the symmetrical sensitive filaments of the great nervous axis of animal life. In the vertebrated animals these optical, acoustic, and other instruments destined to modify the external impressions so as to produce more distinct perceptions, are mostly placed at the ends of the sensitive nerves which issue from the intervertebral foramina of the cranium, and are supplied by other nervous branches indispensible to their function. The circumstances which necessitate the existence of such organs in animals, also require them to be more numerous and varied in higher than in lower tribes, and to be most perfect and delicate where the locomotive powers, and consequently the dangers are greatest. Hence they are more developed in the active insects and other entomoid articulata, than in the slow and torpid mollusca, and are most numerous and perfect in the vertebrated animals where they have to watch over the most complicated and delicate forms of organisation. The columns of nerves appropriated to sensation are greater than those of motion throughout the animal kingdom, and they are spread more extensively through every part of the body, so that almost every point is sensitive to impressions of the density or resistance of outward bodies, to the feelings of heat and cold, and to that of pain when they are injured. This general sensibility, which watches over the well-being of every part of the body, is most acute in the skin, the common covering of all the organs, and the sensations belonging to all the senses are but modifications of this, as their organs also are mostly developments from the cutaneous covering of the body. As the apparatus for digestion are the most important to the maintenance of life, and, next to the cutaneous covering, the most universal in the animal kingdom, the general sense of touch is probably first modified or speciallized at their entrance, to constitute that of *taste* which most immediately relates to this function; and so are successively developed the various other senses of animals, as those of *smelling*, *hearing* and *vision*, of which we are conscious, and which make known the physical or the chemical properties of external objects at greater and greater distances from the sentient body. The sentient nerves are thus very differently modified at their peripheral expande terminations to adapt them for receiving impressions from

bodies directly applied to the skin, or from sapid bodies dissolved in the secretions of the mouth, or from odorous emanations diffused through the surrounding element, or from simple undulations of that element reaching the surface of the body, or from those finer vibrations which constitute the phenomena of light. There may be many other kinds of impressions derived from outward bodies, for which the sensitive nerves of the lower animals are adapted, besides those which affect us, and we cannot always be certain of the identity of the feelings communicated to them by organs which appear analogous to our own. Although we often cannot detect distinct organs for the senses which we ascribe to the lower animals, these organs are commonly enumerated according to the supposed generality of their function in the animal kingdom, from the most general feeling of the nervous system, or the sense of touch to that of vision or of hearing, but the most general *organ of sense* perceptible in animals, as superadded to the nerves of feeling already described, is that of vision which relates to light, so universally diffused through nature, and so influential on both kingdoms of organized beings and even on the constitution and properties of unorganized bodies.

SECOND SECTION.

Organs of Vision.

Many animals, like plants, are affected sensibly by light, without their exhibiting either organs of vision or a single filament of nervous matter. As plants, guided by light, open and close their flowers and their leaves, or follow with their expanded flowers the diurnal course of the sun, or seek his light with their slow-moving branches and their leaves without a perceptible nervous system, so we observe the nerveless gemmules of poriferous animals, and of zoophytes guided by the same agent in selecting a proper place for fixing and developing; the hydra, without eyes or nerves, uniformly moves to the light, the eyeless actinia shuns its influence, and many zoophytes expand or contract their whole body

or their polypi from the influence of this agent though destitute of visual organs.

Distinct organs, however, appropriated to light, are already perceptible in animals where no nervous filament has been detected in any part of the body. Many polygastric animalcules, as the *cercariæ*, are obviously sensible to light, and move towards it like the hydræ, and they generally present on the anterior part of their body one or more small round opaque red coloured spots which have long been recognised, figured, and described as the eyes of these minute animals. Several, as the *euglena longicanda* and *ophryoglena flavicans*, have but one eye, placed on the middle of the upper and anterior part of their body, a monoculous character in which they resemble the microscopic species of some higher classes of animals. Eyes have been detected in most of the genera of polygastrica, down to the monads which are mostly monoculous, and even the minute monad-like beings which unite to form the *volvox globator*, the *eudorina elegans*, and some other remarkable compound or aggregate animalcules, are provided with single red-coloured organs of vision placed near the part of their trunk from which the caudiform vibratile appendix is prolonged. These minute red points of the polygastrica are as obviously eyes, though of the simplest structure, as are those of rotifera where we can perceive their optic nerves and ganglia, and where they have the same red colour and general disposition as in the polygastrica. This superficial or cutaneous opaque spot, to absorb the rays of light, without forming an image of external objects, is the first form of the eye which we see also in annelides and in the larvæ of insects, and the young of higher classes, when that organ is beginning to develop; so that when the optic nerve is superadded to this pigment, or choroid, or coloured rete mucosum, it is first developed behind this opaque matter, as we frequently find it placed in the eyes of invertebrated animals, even when transparent parts are added to collect light, or to form an image of external objects to be transmitted through a hole in this choroidal pigment to the subjacent nerve. The numerous vibratile organs of locomotion, and the rapid movements and free condition of polygastrica require this general development of visual organs in them, while the slow movements or the fixed condition of

most other radiated animals render less necessary in them the development of organs of this nature, and they have not been detected in any of the poripherous or the polypipherous animals, unless the bright coloured opaque points seen on the disk of the locomotive actiniæ, and of some other polypi are organs destined to absorb and to communicate impressions of light. In the acalepha, organs of vision have yet been observed only in the *medusa aurita*, where they are minute round points on the dorsal side of eight brown globules, placed on little peduncles, in the eight depressions around the free edge of the mantle, and they have the same red colour as those of many other transparent animals as polygastrica, rotifera, and entomostracous crustacea. These eight small, red, pedunculated eyes directed upwards, are provided each with a crystalline lens, an optic ganglion, and two decussating optic nerves derived from the exterior circle of nerves which accompany the marginal canal of the mantle, and they are placed near the bases of the marginal tentacula, like the numerous marginal pedunculated shining eyes of a spondylis or a pecten among the conchifera. The organs of vision in the echinoderma, as well as those of the acalepha, have been long figured by authors, though their nature has been till lately overlooked. Beneath the distal extremity of each radiating division of the body of the asterias violacea and asterias militaris, a small, circumscribed, round, red coloured, retractile point is observed, as represented by Vahl, which rests upon a small optic ganglion at the end of each of the five radiating nerves. These are analogous in their position and characters to the common visual organs of animals thus low in the scale, and probably will be found on holothuriæ and other active echinoderma, where the nervous system is most developed. They yet present no transparent parts besides the cornea which has sometimes a glistening or shining appearance even in polygastrica.

The organs of vision, like the nervous and muscular systems and all the other organs of relation, present a high degree of development in the lively and active articulated animals, and they are common in almost every class of this division. From the general structure and habits of the entozoa and the density and opacity of the medium in which they commonly reside, they little require the aid of eyes or of any other or-

gans of sense, and none have been detected in the lowest cystic forms of this class. In the *scolex*, however, among the cestoid entozoa, two minute red-coloured shining eyes have been long observed, and two of a dark colour are found behind the mouth in the polystoma, one of the flat trematoid worms. But these organs are more commonly perceived on those remarkable entomoid kinds of parasitic worms which attach themselves to the surface of aquatic animals, and are in that situation more exposed to the influence of light and of the surrounding element, as various forms of lernææ. The eyes are sessile in these epizoa, and most commonly form a single organ on the median plain, as in many of the entomostracous crustacea which they at first so much resemble. In some the eyes are more numerous, and are placed apart from each other, as in the *gyrodactylus auriculatus*, found attached to the gills of the bream, where there are four minute red-coloured eyes, placed in two pairs behind each other on the back part of the head. In the *achtheres percarum*, there is a single round prominent eye on the fore part of the head, between the two short antennæ, which is very obvious through the coverings of the ovum, and in the young animal in its free unattached condition, and in this species the organ of vision remains through the whole of life. But in the *lernæocera cypinacea*, where the little red coloured circular eye, placed on the fore part of the head, is also distinctly seen in the ovum, and continues throughout the free and entomostracous state of this remarkable animal, it is entirely lost after the metamorphosis and no trace of it can be detected in the adult fixed condition of this parasitic worm. The same disappearance of the eyes has been observed in some of the rotifera. In nearly all the rotiferous animalcules, however, eyes are distinctly observable, of a round form, of a red colour, often two in number, sometimes united to form a single organ, sometimes four as in the *meglotrocha*, or a greater number as in the *cycloglena*, and placed on the upper and fore part of the body. Their constancy, their number, and their high development in the wheel-animalcules corresponds with the general advanced organization and the numerous active organs of locomotion possessed by these minute transparent animals. From the transparency of all their parts and the deep red colour of the

choroidal pigment the eyes of the rotifera, like those of the epizoa and those of most of the higher articulata and mollusca, are very obvious in the embryos while yet within the ovarium, or while the unhatched ova are yet suspended from the exterior of the parent. They are commonly placed near the large supra-œsophageal ganglion, and nervous filaments are sometimes observed distinctly to pass into these organs. They are protected by a smooth transparent and sometimes glistening cornea, and when these little eyes are pressed between plates of mica or glass, the eye-ball is seen to burst, and the deep red pigment, consisting of minute globules united together by a transparent matter, is seen to escape from the ruptured organ. A minute crystalline lens has also been observed in some, behind the transparent cornea. The fixed condition of the cirrhopods in their adult state, inverted in their shell, and the opacity of their exterior covering, afford little occasion for the employment of visual organs in that condition of their life, and they have not been observed in any of the mature animals of this class. Before their metamorphosis, however, in their young and free condition, the cirrhopods possess a distinct black coloured median organ of vision formed by the juxta-position of the two lateral eyes as in many monoculous animals of other classes. These two eyes, formed by the division of one primary organ, appear to be covered with a smooth transparent cornea and to enclose a small crystalline lens, and they are lost by the metamorphosis like the eyes of many other articulated animals.

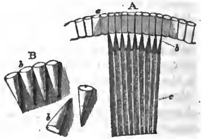
In most of the free annelides there are numerous and very distinct organs of vision, which commonly project shining or glistening from the dorsal surface of the head, and contain a minute transparent lens added to the variously coloured dark pigment and the optic nerve. The eyes are here generally simple, sessile, slightly moveable, and placed apart from each in transverse or longitudinal rows. In the little *prostoma armatum* the head is covered with oculiform points of a dark colour, in the minute *prostoma clepsinoideum*, a small planaria, there are six of these organs, and in other species of prostoma four are observed. Several of the *planariæ* have two deep coloured eyes, in some as the *planaria viganensis*, there is a single row of about forty eyes, passing round all the fore

part of the body, and the same arrangement is seen in the *planaria nigra*, which corresponds with the circular arrangement of the same organs around the margin of the mantle in some of the most active conchifera. The same transverse arrangement is seen in the ten prominent eyes disposed across the head of the medicinal leech. In the *bdella nilotica* there are six eyes disposed transversely on the upper part of the first segment, in the *polynoe impatiens* they are disposed laterally in pairs. The optic nerves of some of the higher annelides are observed to terminate in a broad circular papilla or retinal expansion. The choroid pigment behind the crystalline lens in the medicinal leech is red in the young animal and changes to black in the adult state, as observed in many other animals. In the *nereis nuntia* (Fig. 14) there are four large eyes disposed symmetrically in two pairs on the upper part of the head, and nearly a hundred smaller ocular points disposed in rows and groups on all the prominent lobes around the mouth. In the *syllis monilaris*, there are two pairs of eyes with prominent glistening corneæ disposed on the upper segment of the head. In some of the higher forms of this class, however, as the *euphrosine laureata* and the *œnone lucida*, the visual organs are reduced to two, symmetrically disposed on the upper part of the first segment of the head, and thus approach to the normal character of these organs in most of the higher classes of animals.

In the entomoid classes of articulata, the most active of all the invertebrated animals, the organs of vision are very numerous and commonly aggregated together to form two groups, or two compound eyes symmetrically disposed on the upper or lateral parts of the head—a compound character which commences as low as the rotifera by the approximation of the separate ocular points. The eyes of the myriapods partake sometimes of the character of those of the inferior annelides and sometimes of those of the higher forms of insects, and in some species no organs of vision have been detected. Most of these animals present numerous separate simple eyes grouped together on the two sides of the head. The two lateral eyes of the scolopendra consist each of a group of about twenty-three small distinct eyes approximated and placed in lineal rows, and the aggregate eyes of the iulus are also composed of several rectilineal rows. The *scutigera* has

large eyes like those of an insect, where however the several corneæ are more round and larger than in the compound organs of the true hexapodous insects. The compound eyes of insects consist merely of a closer aggregate of many of these more detached organs of the myriapods, forming hemispherical sessile masses of sometimes ten or twenty thousand eyes on each side of the head, and these are often accompanied by a few small separate simple eyes placed more posteriorly. Lewenhoek calculated 1200 facetts in the eye of a libellula. They are compound even in the apterous *lepisma*, where they are accompanied by three simple eyes, as in many of the higher winged insects, but the coleopterous insects, which approach nearest to the higher crustacea in the concentrated forms of many of their organs, possess only the two compound eyes. The larvæ of the coleoptera and hymenoptera are often destitute of eyes. In the compound eyes of insects the epidermis appears to continue, as we see in serpents, over the exposed surface of the globe, but colourless, and transparent. Beneath this exterior covering are placed the numerous transparent prismatic hexagonal facettes, or corneæ of the several minute component eyes, as seen in the annexed section of a part of the eye of *melolontha vulgaris*, (Fig. 101. A. *a*.) Within this thick continuous exterior layer of aggregated transparent hexagonal corneæ are placed the small conical transparent lenses, (101. A. *b*, B. *b*,) of a regular tapering form and smooth rounded surface, of a firm horny texture and colourless transparency. The hexagonal corneæ of the sphinx atropos are only the sixtieth of a line in diameter. The flat bases of the lenses directed outwards are applied to the inner surface of the

FIG. 101.



corneæ, and their pointed apex is turned inwards to the peripheral or retinal ends of the separate minute optic nerves (101. A. *c*.) These small conical horny lenses are easily scraped off from the inner surface of the cornea when their regular form and smooth surface (101. B. *b*, *b*,) are best examined, and they acquire a whitish opaque colour by the action of alcohol, like the fibrous lenses of the higher classes of animals. They are surrounded by the choroid pigment, and in some insects, as the *libellulæ*, this coloured choroid forms a sort of iris or uvea between the flat base of the lenses and inner surface of the corneæ, and appear to leave space for a small quantity of aqueous humour.

The lenses are very long in the eyes of the libellulæ, where they form lengthened slender nearly parallel cylinders tapering very slightly to the retinal ends of the optic nerves. They are generally shorter in proportion to their breadth in other insects, like those of the melolontha (101. B. *b*, *b*.) The separate slender optic nerves (101. A. *c*,) proceed backwards from the apices of the lenses, though the semifluid pigment or vitreous humour, consisting of variously coloured globules to the great optic ganglion within the globe of the eye, which is almost a prolongation of the cerebral or optic lobes themselves (Fig. 83. D. 1.) The undulations or rays of light have thus an uninterrupted passage in the compound eyes of insects through the outer transparent homogenous epidermic covering, then through the transparent central axes of the prismatic hexagonal corneæ, and lastly through the pupilar openings of the choroid and the axes of the conical hard lenses behind them, where they reach the terminal or retinal papillæ of the several optic nerves, by which the impressions are felt or transmitted to the brain.

Besides these compound eyes, insects in their mature state often present at the back part of the head several simple detached sessile eyes or ocelli, like those common in the inferior articulated classes, and these are alone developed in the larva-state of insects with perfect metamorphosis, as those of orthoptera. In these ocelli of the larvæ, as shown by Lyonet in that of the *cossus ligniperda*, nearly the same structure exists as in each of the component organs in the compound eye of the perfect insect. There are six ocelli in the *cossus*, disposed in a circular order on the parietal lamina,

they have a cup-like form, each is covered with its convex cornea, having a transparent axis, and behind this is the little hard spherical crystalline lens, together with the vitreous humour, the chorid and its pigment, and the optic nerve. Each ocellus receives a branch of a trachea along with its nervous filament, and the tracheæ have been traced also into the compound eyes of perfect insects. Most generally there are three ocelli, in perfect insects, behind each compound eye, on the sides of the head. Some insects, as the claviger, appear to possess neither simple nor compound eyes, nor any other organ of vision, like many of the helminthoid animals beneath them. The eyes of the higher forms of insects are thus numerous, and varied in their directions, from the sessile and immoveable character of these organs, and to suit the rapid and varied movements of these animals; and they compensate for the want of the external protecting apparatus of higher classes, by the density and insensibility of the outward exposed parts of these organs, which they cleanse from adhering matter by the brushes of hair developed on their tarsi, or some other moveable parts. Hairs are often developed from the surface of the compound eyes, originating from the depressions between the hexagonal corneæ, and sometimes the margins of the corneæ are themselves extended outward like the hexagonal tubes of a honey-comb, as in the *stylops*. The eyes of the arachnida are the largest and most perfect forms of the ocelli met with in the articulated classes; like those of the myriapods they are simple and sessile organs, while those of crustacea are compound, like those of insects, and are generally pedunculated. From two to twelve of these smooth eyes are found in the arachnida, and the largest forms of the organs are presented by the scorpions where their structure has consequently been most satisfactorily examined. They are commonly arranged symmetrically in one or two transverse rows on the upper and fore part of the cephalo-thorax, as we observe those, generally eight in number, arranged on the back of the spiders. Beneath the prominent convex cornea in the large ocelli of the scorpion there is a spherical firm transparent lens, more like that of a molluscous or of a vertebrated animal than that commonly found in the entomoid articulata. There is a considerable vitreous humour filling half of the eye-ball, placed behind the crystalline lens,

and surrounded by the pigmentum and the choroid, excepting on the fore part, where it bounds the pupil like an iris, and on the back part, where it is penetrated by the optic nerve. The optic nerve expands into a cup-like retina investing, with the hyaloid membrane, all the convex posterior surface of the vitreous humour. A disposition of the vitreous humour with its retinal and hyaloid membranes, very similar to this, has been observed even in the compound eyes of some nocturnal lepidopterous insects, which is perhaps more general in that class. So that this optical instrument has already all the essential parts presented by the highest forms of the organ, and approaches the nearest to that of the vertebrata. The structure of the simple eyes or ocelli of the mygale and of the tarantulæ appears to be the same as that of the scorpion. The eyes of crustaceous animals are compound, like those of insects; in the higher orders they are pedunculated, and moveable by means of muscles inserted within their exterior hard sclerotic covering; they are commonly sessile and immoveable, like those of insects, in the inferior crustacea; and in the lowest entomostracous forms the two sessile eyes are frequently united on the median plain, to form a single organ, a character approximating these parasitic crustacea to the epizoa and to many other inferior articulata. The internal structure of these compound eyes is nearly the same as those of insects, and was early illustrated by Lewenhoek, who first observed the numerous small conical crystalline lenses within the exterior layer of contiguous prismatic transparent corneæ in the *astacus fluviatilis*. The epidermis in the compound eyes of crustacea passes transparent and homogeneous over the exterior surface of the thick layer of prismatic corneæ, which are here, as in insects, generally hexagonal, but sometimes quadrangular, and to the internal ends of the prismatic corneæ are applied the broad bases of the hard tapering transparent lenses which have their internal truncated apices directed to the retinal expansions of the numerous optic nerves. The whole sides of these transparent conical lenses, as well as the optic nerves extending backwards from their inner ends, are covered, as in insects, with the dark choroid pigment, so that only a small pencil of light gains admission through these long narrow darkened tubes to the small aperture at the posterior truncated ends

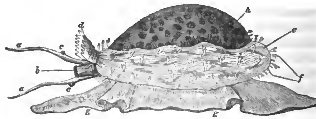
of these lenses, where the optic nerves terminate, as usual, in their small soft retinal expansion. The optic nerves throughout their course in the eye-ball are enveloped in the same dark pigment which coats the lenses. The lenses in the cray-fish and in the *palæmon sulcatus*, are not round in their outline, but four-sided truncated pyramids; most generally, however, they are regular smooth cones truncated at their interior apex, and they are seen of this form even under the smooth and undivided corneæ spread over the eyes of monoculi. In the compound eyes of the *branchipus stagnalis*, however, it has been recently observed that, behind the smooth surface of the corneæ, there are distinct round or ovate lenses supported each on the anterior end of an elongated vitreous humour. This vitreous body tapers backwards to the optic nerve, it is enclosed in a hyaloid membrane which embraces also the posterior half of the lens, and it is entirely covered externally by a retinal expansion of the optic nerve as far as the middle of the lens; thus presenting a structure similar to that lately detected in the compound eyes of several insects. There are about five thousand eyes in the two compound organs of the lobster. The optic nerves in the crustacea, as in insects, enlarge into an optic ganglion within the globe of the compound eye, from which ganglion the small filaments radiate outwards to the separate lenses of the component eyes, and each minute eye appears to have a pupilar extension of the choroid around the anterior surface of its lens. Thus the compound eyes of the crustacea and of insects are but repetitions of the simple organs of the leech and the planaria, and probably of the ocular papillæ of the hydatina, the medusa and the monad. The mobility so remarkable in the pedunculated eyes of the decapods is already perceptible in the elevation and retraction of the isolated organs of the annelides, and this power of varying the direction of the organs is greatly encreased in the pedunculated eyes of mollusca and even of some fishes. In the great development of the cornea and the lens throughout the articulated classes, we observe the early perfection of the most dense and refractive parts, on which the optical properties of this organ chiefly depend.

The organs of vision are less required and less generally developed in the slow moving or fixed molluscous animals

than in the active articulated classes, and they are never aggregated together to form groups of simple eyes, like those of myriapods or arachnida, nor compound organs like those of insects and crustacea. Where they occur in the acephalous mollusca they are numerous, simple, and separate as in worms, but in the higher forms of gasteropods, pteropods and cephalopods their structure is more complex and their number is reduced to two, which are symmetrically disposed on the sides of the head, as in all the vertebrated classes. The tunicated animals, like the cirrhopods in their adult state and like most of the entozoa, fixed and buried under an opaque covering, appear to be destitute of visual organs, and for the same reason these organs are as little required and are wanting in most of the inhabitants of bivalve shells. In the free and quick moving *pectens*, however, which swim rapidly backwards by the quick and repeated contractions of their valves, there are numerous distinct pedunculated eyes, placed at the bases of the palleal tentacula all around the free margins of the mantle, and these have long been figured and recognised by naturalists as organs of vision common to many of the conchiferous mollusca. They are placed in the most exposed and the most sensitive part of the animal, and by their pedunculated character and their position beside the tentacula they resemble the eyes of gasteropods. They are nearly a quarter of a line in diameter and more than fifty in number in the pecten maximus. They have a round prominent smooth cornea and contain an opaque shining choroid embracing a small crystalline lens. Their nerves are probably as in the gasteropods, derived from the tentacular branches passing along the bases of their peduncles. Their forms, distribution and structure are the same in the *spondyli* as in the pectens, and their shining lustre, in both these genera, is compared to that of the emerald by Poli who has given enlarged views of their microscopic structure. The eyes of the gasteropods are always two in number, placed on the anterior part of the body, moveable, and generally pedunculated. Some of the naked dorsibranchiate gasteropods as the *eolis*, the *doris*, and the *glaucus* appear to be destitute of these organs. In the naked *aplysia* they appear as minute black points on the smooth surface of the neck. In the pectinibranchiate species they are most frequently placed on tuber-

cles extended from the bases of the two tentacula, as seen in the annexed figure of the common *cypræa tigres* (Fig 102.)

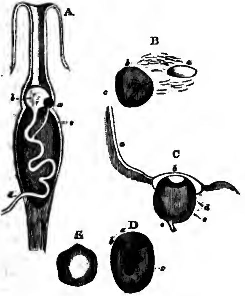
FIG. 102.



from the South Seas, where the two long tentacula (102. *a, a*,) present near their bases two prominent, round, black and moveable eyes (102. *c, c*,) with smooth glistening transparent corneæ. The tentacula being extended above the mouth (102. *b*,) and anterior to the syphon (102. *d*), the eyes, which are raised on tubercles at some distance from the base of the long slender tentacula, have a considerable range of vision. Above the large expanded foot (102. *g, g*), is seen the inner surface of the mantle (102. *e*), turned up over a portion of the shell (102. *h*), and covered with small ramified tentacular extensions (102. *f*), which apprise the animal of danger from behind. In some of the gasteropods, as the *haliotis, limax, helix*, and *onchidium*, the peduncles of the eyes are as long as the tentacula themselves. According to Chiaje the *doris* and the *thetis* have pedunculated eyes, and Ehrenberg has observed organs of vision in the *hexabranchus* and the *phyllidia*. The position of these small dark eyes at the exterior of the base of the tentacula is already represented in the *buccinum undatum* (Fig. 22. *d, d*), and in the *harpa elongata* (Fig. 92. *s, s*,) where they are a little further removed from the base; and in the *carinaria mediterranea* (Fig. 89. *f, f*), where the optic nerves are seen passing to them directly from the cerebral ring (89. *i*). The internal structure of these simple eyes of the gasteropods much resembles that of the large ocelli of the scorpions and other arachnida. In the eyes of the *helix pomatia*, which are raised to the ends of long tubular muscular peduncles exceeding the length of the tentacula, Swammerdam observed a thin aqueous humour, a more consistent vitreous humour,

a pupil and iris, and a distinct crystalline lens; and in the eyes of the *cyclostómum viviparum*, as well as in that anatomised by Swammerdam, a distinct crystalline lens, a coloured choroid coat, and also an iris were detected and described by Stiebel. The structure of the eye in the *helix pomatia* and in the *murex tritonis* has also been described and represented by Muller (Fig. 103). The eye of this *helix* (103. A. *a*), is attached to one side of a large moveable bulb (103. A. *b*), and presents a compressed crystalline lens (103. B. *a*), a thin aqueous fluid, and a larger vitreous body (103. B. *b*), covered by the dark choroid coat. This ocular bulb (103. A. *b*), with its attached eye (103. A. *a*), can be extended from, or retracted into the sheath of its tubular peduncle, and is supplied with a large nerve (103. A. *d*), which gives off the

FIG. 103.



optic (103. A. *c*), as is done by the tentacular branch in most other gasteropods. A similar bulb is seen attached to the eyes in some other mollusca (Fig. 93. A. *c*). Blainville observed a large crystalline lens in the eye of the voluta cymbium, which projected anteriorly like that of a sepia, a small

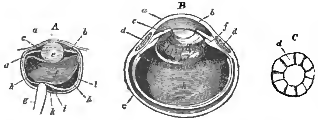
pupilar opening of the choroid behind the transparent skin which formed a distinct convex corneæ over the organ, and two small muscles behind for the motion of this sessile eye. A similar structure nearly was found by Muller in the large eyes of the *murex tritonis* (Fig. 103. C. D. E), where they occupy their most frequent position at the outer part of the base of the tentacula (103. C. *a*). In a few of the gasteropods they are placed on the inner part of the base of the tentacula. The delicate skin of the tentaculum (C. *a*), forms a thin transparent cornea (C, *b*), over the eye and leaves a considerable chamber for the thin aqueous fluid anterior to the iris (103. D. *b*,) and the pupil (103. D. *a*). The eye is lengthened in the direction of its visual axis, and the black circular iris (103. C. *d*. D. *b*), continued from the coloured choroid, presents a large round pupil directed obliquely outwards from the base of the tentaculum. The interior of the large cavity surrounded by the choroid and its pigment, appears to be chiefly occupied by the irregular round pellucid amber-coloured mass of the crystalline lens (103. E), and the optic nerve (103. C. *e*), which comes off from the common tentacular nerve, enters the eye-ball obliquely on the outside of the axis of vision. The organs of vision, two in number and placed on the sides of the head in the pteropods, though small in their dimensions, have probably an internal structure similar to that found in most of the gasteropods. The position of these organs is seen in the *cymbulia* of Peron (Fig. 24. *c*) and in the *clio* of the South Seas (Fig. 67. A, *b*), they are also obvious on the head of the *cleodora*. In the cephalopodous animals these organs present the greatest size and the most complicated structure met with in any of the invertebrated classes, and they are even of great size in proportion to the magnitude of the head and to the general bulk of the body. As in the higher crustacea, and in some of the gasteropods and cartilaginous fishes, the eyes are sometimes pedunculated in the animals of this class as in the *nautilus* and the *loligopsis* (Fig. 93. A. *c*), and they already present distinct external muscles for their movements, and palpebral folds of the surrounding skin, which passes transparent like a conjunctiva over their anterior surface to form a smooth cornea, as in other mollusca. Like the eyes of fishes, they are generally flattened in front from the deficiency of aqueous humour, and they are of great size from the

magnitude of the optic ganglion (Fig. 93. C. *c*), which is greater than the brain (93. C. *a*), and from the glandular masses (93. C. *e*, *e*,) contained within the outer layer of the choroid and the thickened posterior portion of the sclerotic (93. C. *b*), behind the retina and the inner layer of the choroid as in the eyes of fishes. But a small part therefore of these large organs is occupied with the transparent optical apparatus, and their movements are nearly as limited as those of a murex or a buccinum. There is a rudiment of the membrana nectitans, or third eye-lid so generally developed in the vertebrated classes, and the eye-lids, like the iris, are still almost motionless. The ciliary processes, as in the higher cartilaginous fishes, are remarkable for their great development, and the crystalline lens for its double structure and its great posterior convexity; it occupies two thirds of the axal diameter of the eye in most of the naked cephalopods, and consists of two plano-convex hemispheres of unequal size applied to each other by their flat surfaces. The vitreous humour, of a thin fluid consistence, is enclosed in a distinct cellular hyaloid membrane, and the soft loose pigment of the inner layer of the choroid is generally of a deep purple colour. In the loligo there is a small aperture on the surface leading to the glandular cavity of the eye like a lachrymal pore. The retina of the cephalopods is placed, as in other animals, within or anterior to the pigment and the inner layer of the choroid, as shown long since by Chiaje, and the crystalline lens is composed of concentric layers of minute transparent fibres, like that of vertebrated animals. Thus in the isolated organs of vision of the molluscous classes we constantly observe a crystalline lens and transparent parts anterior to the optic nerves as in the higher articulata; and in the general plan of their formation and the higher complexity of their structure they form a nearer approach to the ordinary condition of these organs in fishes and higher vertebrated classes.

The eyes are two in number and symmetrically disposed on the sides of the head in all the vertebrated classes and nearly in all the species, and the differences which they present relate chiefly to the density of the media through which the various animals receive the rays of light, and the extent of development of the external protecting parts of these delicate

organs. From the imperfect development of the nervous system of *fishes* and the obscurity of the element through which they move, their organs of vision are of great size, and from the density of the watery medium around them, they have little necessity for aqueous humour in the eye, and their cornea is flat. To preserve the eye of fishes flat in front, the sclerotic is thickened and consolidated, as in the cetacea, and it is also to prevent its assuming the spherical form in birds, by the equal pressure of the contained fluids, that the sclerotic is there strengthened with osseous plates, which preserve the tubular form of the eye and the great convexity of the cornea in that class. This thickness of the sclerotic coat and the presence of the choroid gland and adipose substance between the layers of the choroid coat behind, and the flatness of the cornea in front shorten very much the visual axis of the eye and diminish the space for containing the vitreous humour; hence a completely spherical form and great size and density of the crystalline lens are here required to bring the rays of light more quickly to a focus as seen in the eye of the perch (Fig. 104. A. *e*). The crystalline lens is

FIG. 104.



composed, as in other classes, of minute transparent fibres, which are disposed in concentric layers and variously united by their serrated edges, the layers encreasing in density from the surface to the centre of the lens. The diameter of the lens (104. A. *e*) is often greater than that of the aqueous and the vitreous humours, and concentrates the rays of light to a focus before the retina, so as to form an inverted image on that membrane. The conjunctiva is now more easily separated from the cornea than in the cephalopods, and the choroid and retina are here remarkable for the distinctness of

the coats of which they are composed. Their eye-lids are still as rudimentary as in the cephalopods, and the liquid element around them is their only lacrymal as well as their salivary fluid. The pupil is large in fishes and the iris is almost motionless. The outer layer of the choroid passes with its shining pearly lustre over the front of the iris, and the dark inner layer lines the posterior surface of the uvea. This inner layer forms a kind of pecten, passing obliquely forwards to the lens, but without the pigment which covers it in birds. The ciliary ligament is always present, but the ciliary processes are rarely developed, and the foramen centrale is not perceptible in the axis of vision. The eyes are generally quite lateral in their direction, and notwithstanding the great irregularity of their outward form, the sphericity of the retina is generally preserved by the glandular and adipose substances interposed behind between the layers of the choroid coat. The sclerotic is easily perceived to be continuous with the sheath of the optic nerve and the dura mater, and sometimes, as in the *xiphias*, the consolidated portion of the sclerotic envelopes the ball of the eye like an osseous band, with a thickened anterior round margin to receive the circumference of the cornea and to support the periphery of the iris. The fatty substance commonly deposited between the layers of the choroid at the back of the eye in fishes is traversed by numerous branches from the ocular artery, and by the ciliary veins returning to the choroid gland. The inner of the two layers of the choroid is often distinctly separable into two, an exterior formed by the straight parallel ciliary veins, and an interior, formed by the ramifications of the ciliary arteries, on which the pigment rests. The optic nerve (104. A. *g*), generally presents a contracted appearance at the place where it penetrates the vascular layer of the choroid (104. A. *k*), and expands into a soft and pulpy retina which terminates by an even margin near the base of the uvea. The organs of vision are smallest in anguilliform fishes and such as burrow in the mud or sand; they are larger in predaceous fishes which frequent the dark depths of the wide ocean than in those which reside on the shallow coasts or in fresh waters; their mobility is encreased in the active muscular plagiostome fishes by being supported on cartilaginous peduncles; they are moved in fishes by

four recti and two obliqui muscles as in higher vertebrata; they are very rarely directed to one side of the head, as in the pleuronectes; sometimes the eye-lids are so perfect as to be provided with distinct orbicular or sphincter muscles; and in several fishes the upper edge of the iris extends down in form of a vine leaf over the middle of the pupil. The pearly lustre of the exterior choroid seems due to crystalline spicula, and from the deficiency of internal pigment the eyes of many cartilaginous fishes have an internal shining lustre, like the tapetum of the eye of quadrupeds.

The eyes of amphibious animals are generally intermediate in their form and structure between those of fishes which receive the rays of light constantly through the dense medium of water, and those of the higher air-breathing classes which receive them through the rare medium of the atmosphere. These organs are still therefore of great size, and flat in front from the small quantity of aqueous humour, especially in the perennibranchiate species which more constantly reside in the water. From the imperfect ossification of the orbit the eyes have great lateral extent of motion, they are provided with an upper and lower eye-lid, and a very complete membrana nictitans, and as in other oviparous vertebrata the lower eye-lid is more developed and more moveable than the upper. The eye is large and provided with a thick and firm sclerotic, as in fishes, in the frog and the toad, but is very small in the pipa where it is destitute of eye-lids, and the crystalline lens is spherical, as in most other amphibia and in fishes. The outer layer of the choroid has the pearly lustre of that of fishes and passes shining over the fore-part of the iris around a pupil still almost motionless, the ciliary processes are not developed, and the retina forms a thick and pulpy external layer like that of fishes. The eyes appear to be still destitute of lachrymal apparatus, as in the former class, and in the proteus the organs of vision are covered over by the opaque integuments of the head.

The eyes of reptiles are more adapted to receive the rays of light from the rare medium of the atmosphere than those of fishes or amphibia, their cornea is therefore generally more convex, their aqueous and vitreous humours more abundant, and their lens less spherical in form. They

are generally provided with the ordinary straight and oblique muscles, a distinct lachrymal apparatus, two moveable eye-lids, and a membrana nictitans. In serpents the skin forming the eye-lids passes transparent and continuous over the eyes and their lachrymal organs, and the epidermis is thus shed from the closed eye-lids as from the rest of the skin; the tears here bathe the concealed conjunctiva, and pass by the lachrymal duct into the nose, as in higher animals. But in the slow-worm, the eye-lids and the membrana nictitans are formed as in saurian reptiles. The sclerotic is sometimes firm and cartilaginous, sometimes it contains adipose substance behind the retina as in fishes, and in many as the crocodilian reptiles, the iguana, the lizard, and the monitor, and the tortoises and turtles, the fore part of the sclerotic supports a circle of osseous plates which surround the transparent cornea, as in birds. These plates around the cornea existed also in the ichthyosaurus. The ciliary processes are now considerably developed around the margin of the flattened lens, especially in the crocodilian reptiles, and the greater freedom and mobility of the iris from the abundance of aqueous humour, allows of more extensive and quick changes in the diameter of the pupil than in the inferior vertebrata. The pupil is often extended vertically in saurian and ophidian reptiles, as in many carnivorous mammalia, and a dark pecten in many lacertine and crocodilian reptiles, is prolonged from the choroid coat into the vitreous humour, as in birds. The pulpy and fibrous layers are obvious in the retina, and its central foramen is seen in many of the species. The eyes of the chamæleon do not move simultaneously, the two eye-lids are united over the eye excepting a small vertical slit opposite to the middle of the pupil, and the concealed membrana nictitans is nearly as large as in birds. In the eye of *emys europæa* (Fig. 104. B.) the cornea (*a*) is pretty convex from the abundance of aqueous humour (*b*) in the anterior chamber, and the margin of the cornea is supported by ten osseous plates (104. C. *d.*) imbricated like those of birds, and placed in the anterior part of the sclerotic (104. B. *d*, *d*,) near to the ciliary processes, (104. B. *f.*) and to the fixed margin of the iris (104. B. *e.*) The crystalline lens (104. B. *g.*) has a compressed eliptical form, and a smaller axis than

the vitreous humour (104. B. *h*.) The retina terminates with a thickened edge at the beginning of the ciliary processes, and a similar structure is presented in most of the chelonian reptiles.

The eyes of birds are adapted in all their parts for the rare medium through which they receive the rays of light, and for sudden changes in the density of that medium, and in the intensity of light, and for the varying distances and directions of their objects of vision, and by their high development and their magnitude they compensate for the imperfect condition of most of the other organs of sense. From the lateral position of the eyes and the great projection of the cornea they command an extensive field of vision, and from this circumstance and the great mobility of their head and their long neck the large organs of vision of birds are less moveable in their orbits than those of quadrupeds. They are the most remote in structure and form from those of fishes, which accords with the difference of density in the media of vision, and the fluids now most abundant in their interior are the least refractive, the aqueous and the vitreous, while the crystalline lens is flattened in its form and reduced in the density of its texture and in the space which it occupies in the axis of the eye. To prevent the sphericity of the eye, from the equal pressure of the contained fluids, and to preserve a great convexity of the transparent cornea especially in rapaceous birds, the anterior margin of the sclerotic is strengthened by a circular series of quadrangular moveable imbricated osseous plates, disposed between its coats around the edge of the cornea as in many reptiles, and which often give a conical or even a tubular form to the fore-part of the eye, as seen in the large nocturnal eyes of the long eared owls. The tough posterior membranous part of the sclerotic, forms a great hemisphere occupied almost entirely by the vitreous humour, and filling the very large orbits of the cranium, and from the quantity of space occupied by the thin and yielding aqueous and vitreous humours in the eyes of birds, they are probably more easily and quickly adjusted to the different distances of surrounding objects, and to the varying density of the medium through which they see. The thin convex dense

cornea is here removed to a distance from the iris by the abundant aqueous humour occupying the anterior chamber, and from the rapid evaporation of this fluid it quickly sinks to flatness or to a concavity externally after death. The cornea is least convex, and the eyes are smallest in the aquatic birds, where the food is often distinguished more by the sensibility of the lips than by the organs of vision, and they are largest in the nocturnal birds of prey where they are directed forwards, with their axes nearly parallel, and the pupils are of great size, to receive the strongest impression from a feeble light. The choroid coat, consisting as usual of two layers, of a dark colour, is lined internally with a thick deposit of black pigment which appears to be composed of globular particles with a transparent centre, and a prolongation of this dark membrane covered with its pigment, is extended forwards through the vitreous humour, from the lineal entrance of the optic nerve to the capsule of the crystalline lens to which its anterior margin is attached. This folded marsupium or pecten, continued from the vascular layer of the choroid through the axis of the eye to the lens, may convey the central nutritious vessels of these humours, or moderate the intensity of the light admitted into the eye, or may assist in adapting the eye to different distances by affecting the position or the form of the lens to which it is attached. From the ciliary ligament which unites firmly the choroid to the sclerotic, the large ciliary processes extend freely inwards to form a corona around the margin of the lens; the ciliary nerves unite to form plexuses at this ciliary ligament, and the retinal expansion of the optic nerve appears to terminate internally at the same place. Plexuses are formed on the ciliary arteries, as in similar delicate organs, before penetrating the delicate textures of the eye to spread on the ciliary processes, the marsupium, and the iris which is here remarkable for the diversities of lively colours which it presents in the different species. From the great mobility of the iris, the round pupil of birds is susceptible of great and rapid changes of dimension, which are very extensive and almost voluntary in the parrots. The optic nerve penetrates the choroid by a lengthened fissure, as in many of the lower animals, and from this lineal perforation the falciform quadrangular pecten extends forwards through the thin and

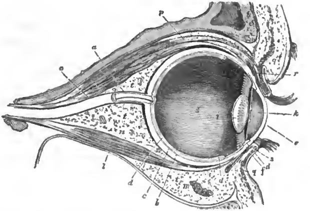
liquid vitreous humour. The bright coloured and highly moveable iris, with its black uvea, appears sometimes detached from the free anterior margin of the choroid, and its coloured surface presents aggregations of minute globules like those of the choroidal pigment. The number of folds in the pecten varies from three or four observed in the goat-sucker to nearly thirty observed in several singing birds. The eyes of birds are moved by the ordinary four straight and two oblique muscles, they are provided with lachrymal glands above and glandulæ Harderi beneath as in many reptiles, their conjunctiva forms always a large pellucid and highly elastic membrana nectitans at the inner angle of the eye moved by two distinct muscles, and their lower and upper eye-lids are very perfect, being already provided with tarsal cartilages, Meibomian glands, and even eye-lashes, besides the ordinary muscles for their elevation and depression.

As some of the *mammalia* are organized to fly through the air, some to walk on the earth or burrow in the interior, and others to swim through the dark abyss of the ocean, their organs of vision are very differently constructed to adapt them for receiving visual impressions in these different situations. They are generally more spherical in their form and consquently more thin and membranous in their tunics, and better provided with external means of motion and of protection, than in the oviparous classes of vertebrata. They have generally a lateral aspect to give greater extent to the field of vision, but in nocturnal quadrupeds and in quadrumana and man they are directed forwards with more parallel axes to give greater precision and strength to the visual impressions. The eyes are large in most of the lower herbivorous mammalia, as the ruminatia, the rodentia and most of the pachyderma, and also in most of the nocturnal species, as we generally find in other classes; and they are very small in the adult state of many of the burrowing quadrupeds, as moles and shrews, in the larger pachyderma and cetacea, in the highest mammalia, where their axes are nearly parallel, and in the cheiroptera, where, as in aquatic birds, their deficiency is compensated for by other organs of sense. The same circumstances which modify the form of the eye and the proportions of its refractive parts in other classes of animals affect the organ

in this : thus in the visual organ of swimming mammalia we observe many affinities with the eyes of fishes, those of bats approach to those of birds, and intermediate forms are allied to the eyes of reptiles. In cetaceous animals, which constantly reside in the water and receive the rays of light through that dense refractive medium, the eyes have little aqueous humour, the cornea is flat, the crystalline lens is large, dense and spherical, and the vitreous humour is less abundant than in terrestial quadrupeds ; and in order to preserve this flatness of the fore-part of the eye, the sclerotic coat, like that of fishes, is here thick, firm, and elastic, especially over the back and the anterior parts of the eye. The sclerotic is an inch thick at the back part of the eye in the whale. The superior oblique muscle of the eye appears still destitute of a pully for its tendon in the cetacea, these lowest aquatic mammalia, and they are almost in the condition of fishes in the imperfect development of their eye-lids and even of their lachrymal apparatus ; but the smallness of their visual organs compared with those of fishes, accords with the higher development of their internal organs of perception, and their whole nervous system. Many intermediate forms of the organs of vision between those of cetacea and those of land quadrupeds are seen in species which have only semi-aquatic habits, as in walruses, otariæ, seals, otters and beavers, where the eye gradually becomes more spherical in form, its coasts around the middle of the eye more thin and membranous, the cornea more convex, the crystalline lens more compressed from before, backwards, and of a softer texture, and the glandular and protecting apparatus of the eye more complicated and more perfect in structure. The large eye of the ruminatia and most other herbivorous quadrupeds accord with the imperfect development of their intellectual organs, and they often present a greater lateral than vertical extension of the transparent cornea, the pupil, and even of the whole eye-ball, by which the lateral range of vision is extended in these timid and watchful animals during the inclined position of the head. The prominent cornea of carnivorous quadrupeds covers a pupil most frequently extended in a vertical direction which is that most suited to their leaping and predaceous habits, and in the back part

of the eye their thick and tough choroid, destitute of the pigment which lines the other parts, shines with a blue or green coloured metallic lustre, a tapetum lucidum which is not seen in the lowest nor in the highest terrestrial animals of this class, and which often presents a red colour, as in albinos, from the exposed vascular layer of the choroid. The ciliary ligament is less and the processes are more developed than in the inferior classes. The iris presents less varied and deep hues than in birds, its free edge, in the embryo, supports the membrana pupillaris which closes the pupil as the inter-pulpibral membrane closes the eye-lids at the same period of life, and where the pupil is elongated transversely, as in the horse, the upper free margin of the iris presents pendent processes, as in the cartilagenous fishes, which hang down more or less over the pupil, and sometimes they rise up also from the lower edge. Between the sclerotic and the choroid is a thin brown coloured layer connecting these coats and considered as continuous with the delicate arachnoid covering of the brain and optic nerve, at the ciliary ligament the minute canal of Fontana is still often perceptible though less than in birds, and the canal of Petit surrounds the lens between the vitreous and the aqueous humour. The optic nerve penetrates the choroid by a round aperture on the nasal side of the axis of vision; but in some of the rodentia, as the marmot, it enters by a lineal slit in the choroid, as in birds, and sometimes a rudimentary transparent pecten is observed in the embryos of mammalia extending forwards through the vitreous humour, as in the lower oviparous vertebrata. As we ascend through the quadrumanous animals to man, the eye becomes smaller and more spherical, its membranes thinner, the vitreous humour more abundant, the crystalline lens smaller and more compressed, the pupil more circular, the ophthalmic ganglion larger, the retinal surface more extensive, the eyes more approximated and parallel, their orbits more completely surrounded with bone, and the circular suspensory muscle extending forwards from around the optic foramen to the sclerotic in the inclined heads of inferior mammalia, is no longer developed or required for the small eyes and elevated orbits of the quadrumana and man. It is however in the visual apparatus of man (Fig. 105.)

FIG. 105.



organized for seeing in the erect position of the trunk, that we find the most complete protection of the orbits by solid osseous parietes and the most parallel direction of their axes. Shaded externally by the eye-brows which are moved by corrugator muscles, and protected by two highly moveable eye-lids formed by the common integuments which continue thin and transparent, as a conjunctiva, over the fore part of the organ, the human eye presents in form of a plica semilunaris, only a small rudiment of the third eye-lid or membrana nictitans so highly developed in most of the inferior vertebrata. The upper eye-lid is now the largest and the most moveable; both eye-lids are supported by tarsal cartilages, they are provided with long cilia symmetrically formed and disposed, and with numerous glandular follicles or meibomian glands, which pour out their secretion by minute pores along the inner margins of the eye-lids, and the eye-lid is perforated within by the several ducts proceeding from the lobules of a large lachrymal gland situate in the upper and outer part of the orbit. There are three or four irregular rows of cilia in each eye-lid, which are more numerous and larger in the upper than in the lower, and increase in size from the two angles to the middle of the eye-lids, the large upper eye-lid has its proper levator muscle which is not required in the lower, and both are closed by the orbicularis palpebrarum. The glandula Harderi so large in the inferior quadrupeds and birds, where the third eye-lid

is fully developed, is here as in the quadrumana reduced to the small follicles of the caruncula lachrymalis, as the great membrana nictitans is now merely a small plica semilunaris at the inner angle of the eye. The lympid fluid from the bilobate lachrymal gland, conveyed by the upper eye-lid over the conjunctiva, passes through the two puncta lachrymalia near the inner angle of the eye, and through the two small lachrymal ducts to their dilated sac and tapering canal from which it is poured by a valvular orifice into the anterior part of the inferior meatus of the nose. The eye-balls, nearly spherical in form, with their axes parallel, and perforated behind by the optic nerves on the nasal side of their axes, are supported on the back part by a large deposit of adipose substance (105. *t. t.*) and are moved by four recti and two oblique muscles; the tendon of the superior oblique is not perforated by the rectus superior (105. *o.*) as it is in many feline animals. The muscles are inserted into the white anterior part of the sclerotic, called tunica albuginea, and the optic nerve perforates a circular cribriform portion of this membrane behind, the central minute aperture of which is occupied by the central artery of the retina which passes through the middle of the optic nerve (105. *a.*) The transparent cornea, composed of homogeneous concentric laminæ, thicker and more convex than the sclerotic, has still its transverse diameter a little more extended than its vertical. The choroid is firmly united to the sclerotic at the white ciliary ligament a line in breadth, and is perforated by a circular aperture behind for the transmission of the optic nerve, and from the anterior margin of this ligament proceed the numerous minute folds of the corpus ciliare which give attachment to about seventy ciliary processes (105, *f.*) extending with their convex margins internally to be united to the capsule of the crystalline lens. The villous internal surface of the vascular layer of the choroid secretes, a layer of variable thickness, of a muscous and viscid pigmentum nigrum this appears to be immediately lined with the delicate transparent membrane of Jacob, within which are the medullary and fibrous layers of the retina (105. *d.*) and the several concentric layers of the hyaloid membrane of the vitreous humour. The iris, composed chiefly of radiating vessels

and nerves disposed in two concentric rings, is attached to the anterior part of the choroid around the ciliary ligament, and divides the cavity for the aqueous humour into two unequal chambers which communicate by the pupil; it is variously coloured on its anterior surface, and supports on its back-part the uvea which is covered with the black pigment of the choroid. A little exterior to the entrance of the optic nerve a small fold of the retina is observed, and a yellow spot, with a minute round transparent portion of the retina, the uses of which are unknown. The vitreous humour (105. *g*.), of a gelatinous consistence and contained within the concentric folds of the hyaloid membrane, occupies about two-thirds of the axis of the eye, and its delicate membrane embraces also the crystalline lens with its firm capsule and forms around its edge the circular canal of Petit. The crystalline lens, here comparatively small and soft, has its posterior surface as usual more convex than the anterior, and both are most convex at the earliest periods of life. The aqueous humour, enveloped in a delicate capsule, which forms the membrana pupillaris by extending over the pupil in the embryo, occupies a large anterior and a smaller posterior chamber, giving the necessary convexity to the cornea and facilitating the free motions of the iris. Thus we observe these complicated optical instruments, the most universal and the noblest organs of sense, gradually advancing to perfection from the monad to man, where all their internal essential parts, and all their external accessary apparatus are the most exquisitely finished and adjusted, and it is chiefly through their means that he is enabled to provide for his wants, to acquire the materials of thought, and to enjoy the sublime spectacle of nature.

THIRD SECTION.

Organs of Hearing.

The organs of hearing are next to those of vision in their importance and in the universality of their occurrence in the animal kingdom, where they are distinctly perceived

both in the molluscous and articulated tribes, and they relate to movements of the surrounding element which give notice of objects at a distance. The percussions given by outward bodies to the air or water in which animals reside, are communicated, like undulations of light, to the general surface of their body, and may produce some feeble sensation where there are yet no distinct acoustic instruments developed, as light appears to affect many organized beings without eyes. But most of the higher invertebrated animals and all the vertebrata present at the distal expanded soft extremities of distinct auditory nerves, more or less complicated acoustic instruments adapted to receive and transmit sonorous undulations, and to render more distinct the perception of their force, their direction and their rapidity of succession. These, like most of the other organs of sense, are disposed symmetrically on the two sides of the head, and the impression of sound may be communicated to the auditory nerves without passing through the external acoustic apparatus, as by means of the solid parietes of the head, or by direct impression on the nerves from within. From the structure of the organ of hearing it is more adapted for communicating aereal vibrations than those of water, and it is most general and most developed in the air-breathing classes. The sudden percussions communicated by various means to the dense watery element in which most of the lower invertebrata reside, may affect rapidly and powerfully the whole surface of their body, whether naked or covered with hard vibratile parts, and through that means the most sensitive internal parts, without these animals having special acoustic organs to concentrate the undulations and direct them to particular nerves, and we ascend as high as the active-air-breathing insects before we perceive distinct organs appropriated to this sense. Many insects have hard organs for producing audible sounds by their rapid attrition against each other, and these sounds are often heard and repeated by their mates, being a means of communication between the sexes, especially in the darkness of the night. The organ of hearing in insects already presents not only a distinct auditory nerve and vestibule, the first and most essential elements of all this acoustic apparatus, but also the rudiments of two semicircular canals, according to the obser-

vations of Camparetti on that of the scarabæus and several other genera of insects. At the lower and lateral part of the head there is a minute round passage closed externally by a membrane, and leading on each side of the head to an internal vestibular sac, with two small curved canals extending from it. These vestibular cavities are furnished with distinct nervous filaments, which appear to be branches of the antenneal nerves, and they constitute an acoustic organ which has been observed in many different forms of this class. They are placed more anteriorly on the head of the locusts, where the minute canals are thin, membranous, and transparent, and this organ presents different degrees of development in different species of locusts. Similar auditory organs have been detected in the *cicadæ*, *vespæ*, *libellulæ*, and at the sides of the base of the long spiral proboscis of the *papiliones;* they are perceived also in ants, flies, and other insects belonging almost to every order of this great class. This delicate organ contained entirely within the cranial cavity of insects is provided with a vestibular opening or fenestra ovalis covered with a thin and tense membrane to receive the sonorous undulations of the air and to convey them to the ento-lymph of these membranous cavities, and so to the expanded surface of the surrounding delicate auditory nerves. These organs have been also dissected and described in many insects by Ramdohr, who observed them in the common bee placed near the base of the maxillæ. Treviramus found those of the blatta orientalis placed behind the basis of the antennæ and closed by an oval, white, concave, vestibular membrane, and Blainville found them in the cicadæ, which distinctly hear, on each side of the back part of the head, in form of two minute open stigmata leading to vestibular sacs, but many entomologists, as Straus and Burmeister, are inclined to place the auditory organs of insects in the antennæ themselves. In the class of arachnida, which also breathe and reside in air, organs of hearing very similar to those of insects were detected by Camparetti in the spiders, placed near to the mouth at the bases of the palpi and consisting of a vestibular sac covered by a transparent membrane, through which the auditory nerves could be perceived. The density of texture and the deep hues of the

exterior covering of the head in these air-breathing entomoid classes, and the softness and transparency of the vestibular membrane which receives the sonorous vibrations, render more obvious the position and nature of the organs of hearing in them, than if the whole exterior of the body were covered with a more soft and uniform skin, and it is probably in part from this circumstance that a more simple rudiment of these important organs has not hitherto been observed in the higher forms of helminthoid animals which already present the rudiments of almost all the complex organs of insects. From the thick and solid calcareous covering of the body in the higher crustacea, their organs of hearing, with their exposed vestibular membrane, are most obvious, especially in the active macrurous decapods, as the lobster and cray-fish, where they present a prominent circular aperture covered with a thin membrane and situate at the bases of the outer pair of antennæ. This exterior covering is calcified in some of the brachyurous species, as the maja, and appears to form a loose operculum provided with distinct muscles for its movements. Within this simple vestibular cavity is a white, soft, lengthened sac, or membranous labyrinth, filled with a transparent entolymph, and supporting the small fibrils of an acoustic nerve derived from the great supra-œsophageal ganglia. It passes obliquely upwards for a short distance into the first segment of the antennæ, and appears to be still destitute of those solid internal lapilli or cretaceous substances which are commonly found in the labyrinths of higher animals. By opening on the lower and not the upper surface of the antennæ, the position of its aperture corresponds with the inverted position of nearly all the other organs of these animals. The extĕrior margins of this vestibular opening, or fenestra ovalis, are often prominent and almost tubular, as in the pagurus, where the covering membrane appears fibrous like the membrana tympani of mammalia. The concealed condition of this organ under a solid calcified covering in the brachyurous species, accords with their more limited powers of swimming, and is analogous to the concealed position of the organs of hearing within the cranium of cephalopods and osseous fishes. These organs have a

large vestibular membrane in the palinurus, they appear as small tubercles in the palæmon, and in most of the inferior orders of crustacea no trace of them can be perceived.

The slow-moving molluscous animals are less provided with organs for perceiving the properties of outward bodies than the active articulated classes; but many of the higher pulmonated gasteropods seem both to hear and to smell, although the precise seats of these feelings have not been determined, and the *tritonia arborescens* emits audible sounds under water, which are, without doubt, intended to be heard by others of the same species, as we see in insects, and probably to serve as a means of communication between these hermaphrodite and almost blind animals, although the organs have not been detected which are appropriated to their perception. The cephalopods which, of all the invertebrata, approach the nearest to fishes in their general form, structure and movements, come next to them in the complexness of their organs of hearing as well as in those of sight. These organs in the cephalopods, as in osseous fishes, are symmetrical and double, placed within the parietes of the cranium, and destitute of external meatus or vestibular membrane. On the sides of the great cephalic cartilage through which the œsophagus passes, and which envelopes the brain, we observe two depressions within the cranial cavity, at its lower part, which are separated by a tough dura mater form the cerebral ganglia. These cavities are separated from each other, and from the exterior muscular parts, by the cartilaginous substance of the skull, and they contain each a membraneous sac, or soft labyrinth, which is surrounded by the exterior lymph of Cotunnius, or peri-lymph. The membranous labyrinth on which the acoustic nerves are distributed is filled with a thin entolymph, and encloses a solid chalky lapillus, of various forms in different species, composed of carbonate of lime, presenting sometimes the appearance of a crystallized rhomboid, and suspended by nervous filaments. Numerous minute blood vessels are seen accompanying the filaments of the acoustic nerves on the parietes of these vestibular sacs. This calcareous substance, like that of the sacculi in the labyrinths of higher animals, serves to communicate more uniformly and distinctly to the accoustic nerves the vibra-

tions transmitted to this part of the head, the organs of hearing being here enclosed in the thickest and densest part of the great cephalic curved plate into which the strong muscles of the arms are inserted. In the octopus ventricosus, this cretaceous body is conical like a limpet, of a rose-red colour on its round exterior tapering surface, white and hollow on the base which rests on the vestibular membrane, and it is connected, as in higher animals, to the side of the vestibule by numerous nervous filaments. The ento- and peri-acoustic lymph seen here in the vestibule corresponds with that found in the entomoid articulata and in the ears of vertebrated animals, and notwithstanding the magnitude and constancy of the auditory organs in the naked cephalopods, and their presenting the most complex form met with in the invertebrated classes, they are yet reduced almost to the first rudiment or most essential element of the auditory apparatus—the vestibular sac with its acoustic nerve.

In tracing this organ upwards through the vertebrated classes we find it gradually perfecting the semi-circular canals, developing a cochlea from the vestibule, and enveloping the whole of this complex labyrinth within the solid texture of the cranium. It acquires in the air-breathing animals a tympanic cavity communicating with the fauces by the Eustachian tube, and containing ossicula auditus which transmit the vibrations of the membrana tympani to the vestibule and the whole internal labyrinth. And in the highest conditions of the organ a still more exterior meatus auditorius and complicated moveable concha are added to complete this acoustic instrument. *Fishes*, like the cephalopods, receive their auditory sensations through the dense watery element they inhabit, the undulations of which strike forcibly the whole surface of their head and trunk, so that they less require any external means of concentrating sonorous vibrations or a complicated internal auditory apparatus, than animals which hear through a thin and rare aerial medium. In the lowest cyclostome cartilaginous fishes, as the lamprey, the whole internal ear is nearly in the same condition as in the cephalopods, consisting of a simple shut vestibule, without fenestra ovalis, enclosed in the cartilaginous substance of the cranium, without internal calcareous

concretions, and even without distinct semi-circular canals, these canals being only represented by three perceptible folds of the vestibular membrane. These two vestibular cavities lodged in the lower and lateral parts of the skull are still separated from the cranial cavity only by the dura mater, and are pierced only by the acoustic nerves and blood vessels which spread on the vestibular membranes, between the peri- and ento-lymph. But in the higher osseous fishes, we find in addition to a highly developed vestibule containing solid calcareous bodies and even sometimes perforated externally by a fenestra ovalis, distinct, large, free, semi-circular canals with considerable ampullæ at their terminations, as in other vertebrated classes. These parts, however, of the acoustic apparatus are not yet imbedded in or surrounded by the solid bones of the head, but are simply lodged in a depression on each side within the general cavity of the skull. There is generally no external fenestra or vestibular opening in osseous fishes, and the sonorous impulses communicated to the body of the animal through the dense medium of the water, are commonly conveyed to the air-sac of the trunk, which is often bifurcated or even ramified, and from that forwards to the base of the skull or into its interior near the ear, and sometimes distinct small costal bones detached from the transverse processes of the anterior vertebræ assist in communicating these vibrations from the air-sac to the organ of hearing. These bones, however, are ordinary elements of the vertebræ, and the air-sac is the rudiment of the lungs and not analogous to the tympanic cavity of air-breathing animals. The great size and length of the semi-circular canals within the cranial cavity of osseous fishes, where they are not yet enclosed within the substance of the temporal bone, corresponds with the great development externally of the tympanic ossicula composing the opercular bones which are likewise unrestrained by any tympanic membrane or osseous walls in their extension outwards. Although in the osseous fishes the whole labyrinth lies in an open groove on each side, entirely within the general cavity of the skull, separated from the brain only by the dura mater, and connected only by ligaments with the temporal bone, we find in the sturgeon, an operculated cartilaginous fish, that the labyrinth is already partly buried in the substance of the

temporal bone, which envelopes the three semi-circular canals and leaves the vestibule still free within the cavity of the cranium. In the higher forms of cartilaginous fishes, however, in the rays and sharks, the whole labyrinth is at length found to be completely surrounded by the firm elastic cartilaginous substance of the skull, excepting at the internal entrances of the vessels and nerves and at the fenestra ovalis which now communicates with an external meatus. The external meatus is already seen in some of the osseous fishes, as in the large ears of the *lepidoleprus;* in the *sharks* it is more distinct though closed externally by the skin, and in the *rays* it is even double on each side as if to form a rudiment of the Eustachian tube, the spiracula of these animals having no relation to the organs of hearing. This imbedded condition of the organ in the cartilaginous fishes better enables them to perceive all the sonorous vibrations communicated to the soft substance of their skull, and we find the whole internal ear preserve this position, so favourable for receiving vibration, even in the densest forms of the skull, from the cartilaginous fishes up to man. The cretaceous substances, generally three in number, found within the vestibular succulum and its communicating smaller sacculi, are soft and pulpy in the cartilaginous fishes and of a stony density in those which have an osseous skeleton. They vary in shape according to the species; they are normal parts of the auditory organ in most animals from the cephalopods to man; they are composed of minute rhomboidal crystals of carbonate of lime and are destitute of internal organization like the excreted shells of molluscous animals. The succuli of the vestibule in these lowest forms of the ear appear to form the first rudiment of a cochlea, and a rudiment of the tympanum is seen in the subcutaneous passage destitute of air, leading from the fenestra ovalis to the surface of the head in the highest cartilaginous fishes. The acoustic nerve comes off separately in fishes from the inferior part of their lobed medulla oblongata beneath the cerebellum, and sends branches to be distributed on the ampullæ of the semi-circular canals, on the vestibule, and on the sacculus or the yet undivided and unconvoluted rudiment of the cochlea, so that its branches are most affected by vibrations in these two last cavities by

the solid cretaceous bodies they contain, and the vestibule and semi-circular canals are the first parts which become imbedded in the substance of the temporal bone. In some fishes, as the *lophius*, where the skeleton is of a semi-osseous consistence the canals are already partially imbedded in the substance of the cranial parietes, by their passing round a process of the temporal bone.

The perennibranchiate *amphibia* being, like the fishes, permanent inhabitants of the water, and receiving their sonorous vibrations through that dense medium, are still destitute of a tympanic cavity, and consequently of a Eustachian tube, which are parts of the organ first required and first developed in those species which lose their gills and change their aquatic for an aerial element. In these aquatic species the labyrinth is still imperfectly enclosed in a spacious general cavity of the temporal bone, the vestibule communicates externally by the fenestra ovalis, to which the stapes is applied as in all the higher classes of animals, but is here in form of an operculum as in fishes. There is no tympanic cavity or membrane; the semi-circular canals and the vestibule with its sacculus and lapilli, are formed like those of osseous fishes, but with the sacculus proportionably small, and the muscles and integuments still cover the exterior of the organ without leaving a trace of external meatus; so that the auditory vibrations from without are here obscurely conveyed, as in fishes, through the solid walls of the cranium. The same simple condition of these acoustic organs is seen in the cæcilia, and appears to be possessed by the larvæ of all the higher caduci-branchiate amphibia. But in the adult state of the frogs and salamanders we find the semi-circular canals already imbedded in the substance of the temporal bone, and the rest of the labyrinth still free in the original general cavity of that bone, as we observe in the sturgeon among the cartilaginous fishes. The lapilli here form a soft white pulpy calcareous substance, and a small tympanic cavity filled with air, communicating with the fauces, and confining the small united ossicula, is now found between the labyrinth and the skin of the head. The Eustachian tubes leading from the tympanum to the fauces, are generally separated throughout, wide, and short, sometimes they unite to open by a single aperture on the median plain as in several frogs and in the pipa, and in

some a canal is found prolonged outwards from the fenestra rotunda. The thin and naked skin forms in these air-breathing amphibia a large membrana tympani on a level with the general surface of the head to the centre of which membrane the bent cartilaginous malleus is attached, and from the soft condition of the tympanic ossicula the sonorous vibrations communicated from without to the large expanded membrana tympani are obscurely conveyed to the fenestra ovalis to which the broad base of the stapes is applied.

In the air-breathing *reptiles* the organs of hearing present a higher condition of development than in the semi-aquatic tribes of amphibious animals, especially in the parts which more immediately relate to the rare medium through which their sonorous impressions are received. The tympanic portion of the ear is still however so imperfectly developed in the serpents that we find it covered externally not only by the skin and muscles, as in fishes and branchiated amphibia, but also by the hard scales of the head. The three tympanic ossicula are united together into a single piece as in the frogs, which is still cartilaginous at its distal or malleal extremity where it is attached to the inner surface of the membrana tympani. The semi-circular canals, with their ento- and peri-lymph as in fishes and amphibia, are imbedded in the dense petrous portions of their solid temporal bones. The vestibule is still lodged in a capacious cavity of the temporal bone, and its sacculus contains a large and solid cretaceous body, so that the solid lapilli of serpents more resemble those of osseous fishes, while the soft and pulpy cretaceous substances of the labyrinth of amphibia are allied to those of cartilaginous fishes, and they are softer in the chelonian than in the saurian reptiles. The cavity of the tympanum is generally much larger in the saurian than in the ophidian reptiles, and is covered externally by a thin, projected, transparent, naked, membranous continuation of the skin, placed on a level with the general surface of the head, so as yet to present no external auditory meatus. This cavity communicates freely with the fauces by a separate Eustachian tube and by means of the fenestra ovalis with the labyrinth, which still presents only a rudimentary undivided cochlea closed externally by the membrane of the fenestra rotunda, and a solid calcareous lapillus as in the serpents. The stapes with its base applied to the fenestra ovalis, continues

to be the principal ossiculum ossified in the tympanum, and the tympanic cavity begins to assume a more lengthened tubular form towards its exterior membrane preparatory to the formation of an external auditory meatus and expanded concha to collect and direct the vibrations of the air. In some of the saurian reptiles the membrana tympani is still covered, as in many serpents, by the ordinary scales of the head, in most it is quite naked and exposed as it is in the frogs and the salamanders, and in the most elevated forms of the sauria it begins to be protected by external overhanging elastic folds of the skin, forming thus a distinct rudimentary concha, as seen in the crocodiles, the gavials, and the alligators. The internal parts of the ear are nearly in the same condition in the chelonian reptiles, which present a more narrow and lengthened tympanic cavity covered externally by the loose integuments of the head, and communicating with the fauces by a wide semi-cartilaginous and distinct Eustachian tube. The three anchilosed tympanic ossicula still constitute a long stiliform bone with its opercular or stapeal piece applied to the fenestra ovalis and attached by its outer rounded malleal extremity to the middle of the membrana tympani as in the other orders of reptiles. The vestibule, enveloped with its sacculus and the semi-circular canals, in the substance of the temporal bone, is provided with solid lapilli supported by the filaments of the acoustic nerves, and with a comparatively large cochlea, though still undivided by an internal lamina and unconvoluted in its form, so that the cochlea appears to be the last part of the internal ear which acquires its normal and perfect form; but in the crocodilian reptiles it already presents a slightly curved form, and an internal membrane which supports branches of the acoustic nerves and divides it into a scala tympani communicating with the fenestra rotunda and a scala vestibuli continuous with the general cavity of the vestibule and membranous labyrinth. Notwithstanding the gelatinous consistence of the ento-lymph which fills the membranous labyrinth of the cold-blooded as well as the higher vertebrata, resembling the vitreous humour of the eye, no cellular tissue or folds of a hyaloid membrane have been observed to pervade its substance, nor in the more abundant and fluid peri-lymph which

envelopes these delicate parts and separates them from the solid parietes of the osseous labyrinth. The soft lapilli of the labyrinth of vertebrated animals appear to consist of minute rhomboidal crystals of carbonate of lime like those often found lining the intervertebral foramina in other parts of the vertebral column.

The dense bones of the skull of *birds* closely envelope every portion of their internal ear with a vibratile covering of great hardness, and corresponding with the rare elastic medium they inhabit. The semi-circular canals, so large and free in the cranium of osseous fishes, are here even more reduced in their dimensions than in reptiles, especially in the water birds, but with enlarged ampulæ at their ends for the auditory nerves. The vestibule is narrow but more lengthened, and the cochlea has assumed a more curved and spiral form than even in the crocodiles, its spiral partition, formed by two triangular cartilaginous folds extending nearly to its apex, partially divides it into a vestibular and a tympanic portion, communicating with the two foramina of the vestibule and communicating with each other at the apex in the dilated infundibulum or lagena. The cretaceous lapilli so large in the membranous labyrinth of fishes and amphibia are now greatly reduced and appear only in the form of strata of minute calcareous crystals. The semi-circular canals are long and narrow in the rapaceous birds, large and wide in the singing birds, and comparatively small, short, and wide in the grallatores, the palmipeds, and the gallinaceous birds. The tympanic cavity, lengthened like the vestibule, has here a short external meatus beyond the projecting convex membrana tympani to which the cartilaginous malleal end of the anchylosed tympanic ossicula is attached. Not only the tympanic cavity is here surrounded by solid bone, but also the short wide Eustachian tubes which sometimes unite together before they open into the posterior nares, and the drum of the ear has its internal dimensions greatly encreased by the numerous air-cells of the diploe, over the greater part of the cranium, which now communicate freely with the interior of both tympana. The short external auditory meatus removes the membrana tympani from the level of the general surface of the head, and the exterior concha, the last part of the auditory organ to be developed, presents itself as a simple

crescentic fold of the skin extending upwards from the superior margin of the external meatus. This rudimentary concha is perceptible in most birds, which can erect or depress the feathers which bound its upper margin, but it is most developed in the nocturnal predaceous birds, which most require this sense to direct them to their prey in the night. The extent of this crescentic membranous concha is encreased in some of the owls by the long feathers which radiate from around its free margin, and it is raised or depressed at will like a valve or an eye-lid. The solid parietes of the tympanum are pierced by several foramina which lead to the large cells between the two tables of the skull, as those in the tympanum of man and quadrupeds lead to the mastoid cells, and the tympanic cavity is here traversed by the vidian nerve as in mammalia. The cartilaginous malleal portion of the single long tympanic ossiculum divides into three parts where it is attached to the inner surface of the membrana tympani, but in place of the three muscles of the malleus observed in man and quadrupeds, there is here but one long muscle which extends forwards from near the occipital condyle to the exterior end of the malleus.

We thus arrive at the most perfect condition of this complex acoustic instrument presented by the *mammiferous* animals, where all its internal essential parts and all its external accessory apparatus have attained their full development. The petrous portion of the temporal bone, of great density, embraces closely all the most important internal parts, and the exterior concha for collecting the sonorous vibrations and directing them to the membrana tympani, is generally of great size. The thin membranous labyrinth, highly vascular and of exquisite delicacy, is filled with a fluid ento-lymph enveloping two cretaceous bodies composed of minute calcareous crystals, and analogous to those found in the labyrinth of fishes and even of many invertebrated animals. These two cretaceous bodies, nearly of equal size, are contained, one in the large sacculus of the vestibule, and the other in the long elliptical sacculus formed by the meeting of the semi-circular canals near their ampullæ, and they are supported by the delicate expanded extremities of distinct branches of the acoustic nerves as in the inferior classes. The membranous labyrinth is surrounded

externally with a copious transparent, thin and colourless peri-lymph which separates it from the periosteum, lining the interior parietes of the osseous labyrinth. The membranous semi-circular canals and their ampullæ are comparatively slender, their median portion forms the larger part of the broad, short, and irregular vestibule, and its lapillus corresponds with the utricular of fishes. The sacculus vestibuli and its lapillus are proportionally small, and the cochlea forms a large turbinated cavity divided longitudinally throughout by an internal solid spiral lamina, forming from two to four spiral turns; but in the ornithorhyncus it is as simple as in birds. As in the inferior vertebrata the exterior semi-circular canal extends outwards horizontally and at right angles to the other two, and the anterior and posterior unite together to form a common canal before entering the vestibule, their direction being nearly vertical with relation to the floor of the cranium. The nerves of the membranous labyrinth are chiefly confined to the ampullæ of the semicircular canals and to the two sacs containing lapilli, and the two lapilli are proportionally larger in the fœtus than in the adult. The osseous spiral lamina dividing longitudinally the interior of the convoluted cochlea is still membranous at its peripheral margin, and the scala vestibuli communicates freely with the scala tympani at its dilated apex where it receives a branch of the acoustic nerve, but no nervous branches are perceived on the membranous semi-circular canals. The two vestibular openings vary much in their form and size in different mammalia, and the aqueducts of the vestibule and cochlea appear connected, the one internally with the dura mater and the other externally with the periosteum. The cochlea is of a narrow lengthened spiral form in many of the rodentia, more short and orbicular in the cetacea, and in most of the higher orders of quadrupeds it forms a turbinated cavity with about two turns and a half as in the human ear. The tympanic cavity, imbedded in the temporal bone, communicating by several apertures with the mastoid cells, and by a lengthened ossified Eustachian tube with the fauces, is bounded by a thin fibrous membrana tympani concave externally, and contains four ossicula articulated moveably with each other and provided with distinct muscles for their movements. The external

meatus is now increased in length, bounded by ossious walls, defended internally by short hairs and by an acrid secretion from its parietes, and generally terminated externally by an expanded cartilaginous concha variously formed and developed, which is adapted by its mobility and its conical shape to collect the sonorous vibrations from different directions and to convey them to the internal ear. The concha is generally very small or wanting in the aquatic mammalia. In the cetacea, where the cochlea is often very large and the semi-circular canals comparatively small, we observe only a narrow winding perforation leading outwards from the membrana tympani to the surface of the head, there is no external concha, and the minute entrance to the meatus is scarcely perceptible on the surface of the skin. The concha is still wanting in the seals and walruses, and is very small in otariæ, beavers, otters, and other diving mammalia. It is deficient in the ornithorhyncus, and in several digging animals, as the mole and the manis. The monotrema are also distinguished by several other marks of inferiority in their organs of hearing by which they are allied to birds and reptiles, as the shortness of the external meatus, the anchylosis of the ossicula auditus, the rudimentary state of the cochlea, and the free projection of the osseous semi-circular canals into the cavity of the cranium. As we ascend through the tribes of mammalia that live more exclusively upon the land, we find the exterior cartilaginous concha acquiring greater magnitude and symmetry, and, by the articulation of the cartilage and the great development of its muscular apparatus, it acquires the means of more varied and extensive motion. It is largest, most moveable, and, commonly directed backwards, in the timid and feeble rodentia, ruminantia, pachyderma and other herbivorous quadrupeds where the cerebral hemispheres are proportionally small, and it is least and directed forwards in the carniverous tribes where the brain is large. It is large, however, in the bats and most nocturnal quadrupeds, and we observe it in the quadrumana, especially in gibbons and orangs, gradually acquiring the short, flat, round form and motionless character of the human concha. The internal ear of man, like that of inferior mammalia, has its membranous labyrinth filled with an ento-lymph and separated by a thin

peri-lymph from its osseous parieties. The auditory nerves, as in other vertebrated animals, spread on the ampullæ of the semi-circular tubes and supporting the cretaceous lapilli of the median sinus and the succulus, can receive their impressions only from the undulations of this fluid medium. The minute component crystals of the two cretaceous lapilli of the vestibule are loosely aggregated together as in the cartilaginous fishes and in all the higher vertebrata, and the membranous labyrinth is separated from the fenestra ovalis by the peri-lymph and by the membrane of that orifice, so that this thin enveloping peri-lymph receives the sonorous vibrations from the tympanum and transmits them to the sensitive parts of the membranous labyrinth. The aqueducts appear to be but vascular foramina. The anterior auditory nerve, accompanied by the facial, passes to the two anterior ampullæ and to the cretaceous lapillus of the median sinus, and the posterior auditory branch passes to the posterior ampulla, to the saccular lapillus, and to the cochlea, as in the inferior vertebrated classes. So that there is great uniformity of plan in the structure of this delicate acoustic organ from the simple vestibule of the articulata to its most complex form in the highest mammalia, where the different densities and forms of the pulpy granular lapilli, the gelatinous ento-lymph, and the thin fluid of Cotunnius, regulate and limit each others vibrations, and approximate the phenomena of hearing to the undulations of light through the various humours of the visual organs.

FOURTH SECTION.

Organs of Smell.

The organs of smell, which are destined to receive and transmit the impressions of odorous particles diffused through the medium in which animals live, are much simpler in their structure, and more difficult to determine, in the inferior tribes of animals than those of sight or hearing, and they appear also to be less important for the preservation of life, and less general in their occurrence throughout the animal kingdom. It does not appear that the radiated

animals have distinct organs to enable them to be sensibly affected by odorous effluvia, but the air-breathing annelides among the articulata have been supposed to perceive them by the parietes of their mouth or by the lateral pores of their air-sacs. The sense of smell so distinctly manifested and so delicate in insects, has also been referred to the same parts of their body, or to their palpi, or to their œsophageal sacs, or to the delicate subdivided laminated extremities of their long flexible antennæ, and the inner pair of these organs in the crustacea have been considered as the seat of the same sense. The labial appendices of the conchifera and other molluscous classes, the entrance of the respiratory sacs in pulmonated gasteropods, the highly sensitive tentacula covered with a delicate mucous membrane, and even the whole surface of the skin in the higher mollusca, have been regarded as the organs through which these animals receive impressions of odorous emanations.

The organs of smell, on which the olfactory nerves are entirely distributed, are very obvious in fishes, although they do not communicate with the respiratory organs or with the cavity of the mouth. They are laminated organs placed in cavities or depressions excavated on the anterior part of the face and protected by cartilages as in higher animals, but have yet no posterior opening into the interior of the body on account of the density of the element here respired. The olfactory nerves, arising alone from the rudimentary hemispheres of the brain and provided with large olfactory tubercles, perforate the anterior part of the skull corresponding with the ceribriform plate of the ethmoid bone, and immediately spread upon the numerous parallel or radiating laminæ covered with a delicate and extensive mucous membrane. These numerous nasal laminæ covered with the petuitary membrane are thus more or less exposed on the surface of the face to the contact of the surrounding element, and a fold of the integuments supported by a cartilaginous plate generally hangs like a valve over the middle of each nasal cavity. The nasal cartilage protecting each cavity partially divides its entrance into two, so that the water passes freely through its interior and over the extensive surface of the olfactory laminæ during the lateral motions of the head and the progressive movements of the

body. By the separation of the organs of smell from the respiratory passages in fishes, as in other water-breathing animals, their great sensibility and delicate structure are protected from the violent and incessant action of the currents of water required for respiration. In most osseous fishes there is an anterior contractile and a posterior open or valvular orifice placed superficially apart from each other, and leading into each nostril from the upper part of the muzzle, but in the lampreys both nostrils open by a common orifice on the upper part of the head. In the plagiostome species the wide plicated valvular nostrils open on the under surface of the face anterior to the mouth, and in some of the eels an approach is made to the structure of these parts in the lowest amphibia by having the posterior orifice of their nostril placed internally under the upper lip.

In the amphibious animals, where the respiration of air begins to be effected through the nostrils, the olfactory organs become more complicated in structure and more internal in their position. The cartilaginous plicated portion of the organ of fishes now begins to assume the more compact tubular and convoluted form which the osseous plates present in the higher classes of animals, and the sensitive surface of the organs increases in extent as we ascend through the vertebrated classes. In the perennibranchiate amphibia the nostrils still form on each side a simple sac, without internal convolutions, and having their posterior opening so far forward in the mouth as to be immediately under the upper lip, as in some fishes. In the larva state of salamanders and frogs the nostrils are still, as in fishes, confined to the exterior of the head, and even in the adult forms of these animals the posterior openings of the nostrils, though within the cavity of the mouth, are much advanced in their position, and distant from the median line of the body. The exterior nares which are muscular and contractile, have now almost lost the cartilaginous valve of the fishes, but the turbinated bones even in a cartilaginous form, scarcely yet extend the interior surface of the organ, and the cavities of the nostrils in the proteus are still laminated as in a fish, although they open posteriorly under the upper lip.

In the serpents the organs of smell have their internal surface extended by the rudimentary turbinated bones, and

by enlarged nasal cavities which open posteriorly both by a common orifice on the median plain, near the anterior part of the palate. These cavities are increased in the sauria where the turbinated bones begin to be strengthened by ossific matter and to assume a more convoluted form. They extend from the point of the muzzle nearly along the whole head, separated by the vomer, in the alligators, gavials and crocodiles, where they generally open externally by expanded, contractile, valvular sacs, as in many cetacea. The anterior and posterior openings of the nares, in the saurian reptiles, are wider than in the ophidia, the whole organs are situate more internally and are more protected by the expanded nasal bones. The whole organs of smell are still more covered and concealed by the osseous walls in the consolidated head of the chelonian reptiles, where the olfactory surface is encreased in extent, the anterior nares are very small, and the posterior openings are placed further backward from their primitive anterior position in the inferior vertebrata.

The olfactory nerves and the whole internal organs of smell are comparatively small in birds, and their imperfect development of this sense is compensated for by their high powers of vision, which is better adapted for their active life and the great distances at which they generally require to distinguish their food. The exterior openings of the nostrils are generally large and oblique for the more free respiration required during their rapid movements; they perforate the horny mandible or the cere, or the feathered skin, and the various forms and positions of these exterior openings present useful characters for the distinction of species in this class. There is commonly a nasal gland of considerable size in or near each orbit. The cartilaginous alæ of the nose are seldom moveable or prolonged, the septum is often more deficient below than that between the orbits, and the posterior nares, prolonged backward to near the glottis, often terminate by a single opening covered with protecting papillæ. The turbinated bones are larger than in reptiles, and the convoluted portion of the ethmoid, though they are still but partially ossified, and the olfactory nerves pass from their long ethmoidal tubes, through the back part of the orbits, into the convoluted plate of the ethmoid.

These convoluted parts for the highly vascular petuitary membrane, and corresponding in magnitude with that of the olfactory nerves of birds, are for the most part still cartilaginous and very limited in their extent, and the imperfect development of this organ is often compensated for by the extensive distribution of the fifth pair of nerves on the upper and lower jaws, as in many aquatic species which seek their food in mud.

All the internal parts of the organs of smell become more complex and elaborate in the mammiferous animals, new and enlarged cavities open into their interior, as the frontal, maxillary, and sphenoidal sinuses, the large nasal glands of birds are here reduced to follicles, and the exterior nares assume a more lengthened and expanded form than in the oviparous classes. The large olfactory nerves here penetrate the numerous openings of a broad cribriform ethmoidal plate, excepting in the cetacea, and spread over the very extensive surface of the convoluted cellular part of the ethmoid, and the two turbinated bones on each side. The turbinated bones are most lengthened and simple in form in the long-muzzled ruminantia, pachyderma, and other herbivorous quadrupeds, where the various communicating sinuses are largest, and these bones form the most complicated labyrinths in the short-muzzled carnivora, where the sense of smell is most acute, and by which they pursue their prey through all their windings and concealments, or seek them by night. The exterior openings of the nostrils are valvular in the beavers, seals, and other diving quadrupeds, to protect them during their rapid movements through that dense element; they are almost as valvular in the camels and dromedaries for the sands of the desert, and in many scraping and burrowing quadrupeds, and they are prolonged in many cetacea into wide valvular and contractile sacs, which enable them, like the crocodiles, to breathe freely with every other part of their body concealed under the surface of the water. The nostrils terminate in vertical foliated membranous expansions in the phyllostoma and many other bats, and in fimbriated radiating margins in the condylura; they form the digging instruments in the hog tribe; they are long and flexible in the nasua, more muscular, prolonged, and mobile in the tapir, expanded into a bottle-

shaped cavity in the cystophora, and most extended in the elephant where they serve as organs of prehension both for fluid and solid food. Where the cerebral hemispheres in this class are largest, the olfactory, like most of the other sensorial organs, are comparatively small, as in the quadrumana and man, and they are proportionally large in the human fœtus and in the negro, as in the inferior orders of mammalia.

FIFTH SECTION.

Organs of Taste.

The organs of taste are situate in the mucous membrane of the mouth, especially in the papillæ and calyces of the tongue, and are adapted to convey a knowledge of many properties of sapid bodies applied to these parts; so that, as the organs of smell watch over the respiratory organs and the properties of the surrounding element, those of taste are situate at the entrance of the digestive apparatus where they can best examine the materials to be conveyed into the alimentary canal. According to the extent and delicacy of these parts of the mouth, and their supply of blood vessels and nerves, the sense of taste appears to be developed in animals, and the gratification of this sense forms an incentive towards supplying the necessary wants of the body. Although these organs appropriated to our sense of taste are more rarely met with in the inferior animals than the organs of the former senses, it is difficult to conceive animals with a mouth and stomach without supposing that they derive some sensations of taste from the substances they introduce as food into these cavities, and such sensations have been ascribed even to the polygastric animalcules, from their apparent selection of proper food, and their rejecting hurtful substances. Where delicate buccal organs, of doubtful function, are directly applied to the food in the lowest tribes of animals, it may be inferred that they communicate some impressions of this kind, as the prominent lips of many polypi and acalepha, the minute tubular organs around the mouth of ophiuræ, asteriæ, spatangi, and most other echinoderma, and the tongue and lips of most articulated and molluscous animals. Notwithstanding the shortness and

density of the tongue, and the horny prehensile or masticating organs which often cover its surface in higher classes, we can perceive distinct gustatory villi on that of the cephalopods and the cold-blooded vertebrata, which are succeeded by larger papillæ and calyces in the birds and mammalia. These highly vascular and sensitive papillæ which terminate the gustatory filaments of the fifth pair of nerves gradually assume the arrangement and forms which they present on the human tongue as we ascend through the quadrumana to man.

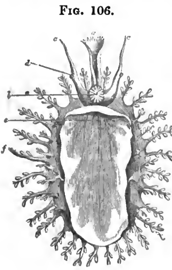
SIXTH SECTION.

Organs of Touch.

The most general sense in animals is that of touch, of which all the others may be mere modifications, and it is situate in the highly vascular and sensitive surface of the skin which covers and protects the entire machine. This general sense relates to the most common physical properties of bodies, as their form, their consistence and their temperature, without some perception of which animals could scarcely provide for their own subsistence or the continuance of their race. It constitutes the simplest form of an organ of sense, where the minute cutaneous vascular papillæ are scarcely yet apparent, which form by their development on the ends of sensitive nerves the more complicated organs of the higher senses; and the contact of the outward object, required in all, is most obvious in this sense. As the sensitive surface of the skin, the vascular layer of the corium, exudes upon its exterior an insensible and extra-vascular cuticle and rete mucosum, which vary much in their thickness, and in the nature and quantity of the materials which often consolidate them, the effect of external impressions in exciting perceptions of touch must chiefly depend on the structure and sensibility of the parts touched and on the general condition of the nervous system in animals. Those invertebrated animals therefore, of each class, which have their exterior naked and soft, will have a more general and acute sense of touch than such allied forms as have their bodies covered with dense substances, although in the latter animals the higher development of the other

organs of sense may compensate for the deficiency, and enable them amply to provide for all their wants. The naked surface and long *cilia*, almost developed into tentacula, of most polygastric animalcules, the long sensitive *tentacula* of most zoophytes and acalepha, and the fleshy tubular feet of higher radiated animals, are the parts most adapted to receive impressions of this kind, although we perceive no distinct organs in these animals appropriated solely to the sense of touch. These sensitive organs continue soft in the helminthoid articulata, but become consolidated and jointed in the entomoid classes where they constitute the various forms of *palpi* and *antennæ*. There is one pair of these antennæ in the myriapods as in most of the annelides, and the same number is seen in the insects, but they are deficient in the arachnida, and two pairs are found in the crustacea where they are generally more extended than in insects. In the molluscous classes they again assume the soft, sensitive and fleshy condition of *tentacula*, destitute of articulations, as we observe around the orifices of the respiratory sac in unicated animals, and around these orifices and the margins of the mantle in conchifera. In the gasteropods there are commonly two of these tentacula, as seen in the *cypræa erosa*, (Fig. 106. *c. c.*,) they extend from the sides of the neck or the mouth, (106. *b.*,) supporting the eyes (106. *d. d.*,) near their base, and are often surmounted by the ciliated syphon (106. *a.*) for the passage of water to the respiratory organs. The muscular foot (106. *e.*) possesses exquisite sensibility; there is frequently a second pair of tentacula at the sides of the mouth, and numerous fleshy extensions, simple or ramified (106. *f.*), are often seen prolonged from the sides or the general surface, of the mantle. Similar fleshy cephalic tentacula are seen

Fig. 106.



in the pteropods, and the whole surface of the body is exquisitely sensitive in the naked cephalopods where the flexibility of the long arms and tentacula will enable them to obtain more accurate perceptions of the forms and dimensions of outward objects.

Among the vertebrata, as in the inferior classes, many animals are covered externally with hard and insensible parts which must greatly obscure their impressions of touch derived from the contact of surrounding objects. The large solid calcareous scales of many fishes, the smaller horny scales of most ophidian and saurian reptiles, the large plates of crocodilian and chelonian reptiles, the compact and dense plumage of birds, the thick hides or shaggy furs of many quadrupeds, and the long spines or broad horny scales of others, must act like the insensible sheaths of many radiated, articulated, and molluscous animals, in shielding their skin from impressions of touch. Many fishes have the scales so minute that their body, with relation to touch, is almost as naked and sensitive as that of the amphibia above them; others have only the lower surface of their body or the periphery of their mouth covered with a naked and sensitive skin to compensate for the want of adaptation of the arm and hands to the sense of touch, and in many species of fishes the tentacula of the inferior classes are still seen in the form of fleshy filaments around or near the mouth. The long divided exsertile tongue of serpents and the worm-like flexibility of their trunk compensate for the want of hands as organs of touch. The flexible prehensile tails of many climbing saurian and mammiferous animals, the palmated feet and sensitive lips of many aquatic birds and mammalia, and the delicate exposed skin, the extended labial bristles, the long flexible tongue or lips, or the extended proboscis of many quadrupeds, contribute to extend this sense. The osseous foramina for the branches of the fifth pair, even in animals now extinct, enable us to judge of the development of these parts relating to the sense of touch. But, from the cold-blooded amphibious animals through all the higher forms of terrestrial vertebrata, we observe the hands to become more exquisitely organized and more fitted for communicating delicate impressions of the forms, dimensions, temperature,

consistence, and other physical properties of external bodies. The almost naked skin of apodal anguilliform fishes, and the great flexibility of their trunk, compensate, as in the perennibranchiate amphibia and in the cetacea, for the imperfect development of their members as tactile organs, and many fishes possess tentacular filaments of great sensibility, and often very numerous near the mouth, as the sturgeons, the *silurus*, the cod, and the *lophius* where they extend also from along the sides of the body. The clawless feet, the naked and delicate skin, and the broad fleshy tongue and lips of the caducibranchiate amphibia greatly extend their means of receiving impressions of touch; and the long forked tongue of serpents, during their intercourse with each other, and during their progressive movements, is constantly darted out and retracted, and employed as an organ of touch, like the antennæ and palpi of insects under similar circumstances. The soft webbed feet and partly clawless toes of the crocodilian reptiles, and their broad fleshy tongue and lips, compensate for the diminished sensibility produced by the large ossious plates and horny scales covering the greater part of their body, and enable them better to feel their prey under the dark and muddy waters they inhabit. The broad digital expansions of geckos and phylluri, the soft fleshy feet and thin cutaneous coverings of the chamæleons, the iguanas, the lizards, and other climbing sauria, and the broad intercostal membranes of the dragons, contribute also to extend their sense of touch. As in all other aquatic animals, it is chiefly among the aquatic forms of birds and mammalia that we observe the naked and soft condition of the skin most conducive to its sensibility, and the most extensive development of this delicate organ of touch especially between the digital phalanges, and the tentacular developments of the invertebrata so often seen in the fishes, are still observed in various fleshy prolongations from the face of birds, and even of some quadrupeds as the condylura. It is, however, chiefly in the long divided hands of carnivora, quadrumana, and all the higher forms of quadrupeds that we find the organs of touch acquire their most appropriate and exquisite structure. And in proportion to the high nervous development and that of the sensitive cutaneous papillæ, to the sensibility, the vascularity, the flexibility and the softness of the fingers,

the hands and other cutaneous parts, this most general sense of touch, so closely allied to common nervous sensibility, encreases in power and extent as we ascend to man, who surpasses all other animals in the exquisite and equal development of all his organs of sense, and in the perfection of all those higher organs of relation by which animals are more immediately connected with surrounding nature.

PART SECOND.

ORGANS

OF

VEGETATIVE OR ORGANIC

LIFE.

CHAPTER FIRST.

ORGANS OF DIGESTION.

FIRST SECTION.

General Observations on the Organs of Digestion.

As an animal is but a moving sac, organized to convert foreign matter into its own likeness, all the complex *organs of relation* or *of animal life* serve but to administer to this digestive bag. The *bones,* connected together by their *ligaments,* are but the solid levers which enable the *muscles* to move it to and fro, and the *nervous system,* with its various *organs of sense,* serve but to direct its movements in quest of food. The unorganized food of plants is placed by nature in contact with the exterior surface of their body, and their vessels are directed thither to select and absorb it, which roots them through life to the soil where they grow; but as animals place their food within their stomach and have their roots directed inwards to that central reservoir, they can change their place and move about in quest of what is most congenial to their nature. The *organs of animal life* relate to this difference between the two organic kingdoms, to the locomotive powers of animals for the selection of their food; but the *organs of vegetative life* relate merely to the assimilation of food when already within the body, and are, therefore, common to animals with

plants. The alimentary surface of the plant is the exterior of its root, ramified and fixed in the soil which affords it food, so that a vegetable is like an animal with its stomach turned inside out. As the organs of relation are those most immediately connected with the varying external circumstances of animals, they are the most variable in their character and inconstant in their existence; but those of vegetative or organic life relating to the more common and necessary functions of assimilation are much more regular and constant in their character. No organ, indeed, is more universal or essential in animal bodies than that internal digestive cavity by which they differ so remarkably from the species of the vegetable kingdom. This internal sac is but an extension of the primitive absorbent surface of the skin, which, in animals, passes into or through the homogeneous cellular tissue of the body. And, although in the simplest forms of animals, this primitive sac performs alone all the assimilative functions, we find it, as we ascend in the scale, giving origin to various other organic systems, to which distinct parts of the complex function of assimilation are successively entrusted. Thus the peripheral nutrition of the plant passes gradually into the central mode of the animal, and the organs of organic or vegetative life, whether they open internally into the digestive cavity, or on the mucous surface of the skin, may be considered as originating from the exterior integument, which is itself only a portion of the primitive cellular tissue of the body, modified by the stimulating contact of the surrounding element. As the various tubular prolongations of the alimentary canal become more and more developed and isolated from their primitive source, they assume properties and functions more and more peculiar and distinct, and thus form the numerous follicular and conglomerate glandular apparatus, and the various vascular systems, of animals. An alimentary cavity is observed in every class of animals and almost in every species, and its form and structure vary according to the situation of animals in the scale, or according to the kind of food on which they are destined to subsist, and the extent of elaboration it requires to undergo to assimilate it to the animal's body. The peculiarities presented by the digestive organs are, therefore, intimately connected with the diversi-

ties of form manifested by the organs of animal life, and with all the living habits and instincts of animals.

SECOND SECTION.

Digestive Organs of the Cyclo-neurose, or Radiated Classes.

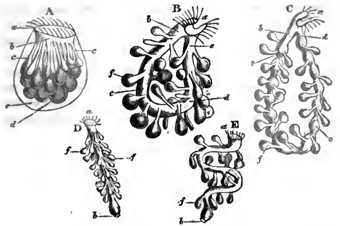
In the lowest tribes of animals the internal organization relates almost solely to digestion, and the food consists almost entirely of the simplest forms of animal matter. The alimentary cavity has often but one orifice, it is seldom provided with masticating organs, and scarcely a trace of any glandular organ is yet observed to assist in the process of assimilation. Like the exterior form of the body, the digestive apparatus is more varied in this than in any of the higher divisions of the animal kingdom.

I. *Polygastrica.* Internal digestive cavities are seen in the simplest monads; and they are so numerous in almost all the higher forms of animalcules, that the class has been termed polygastrica from this character. From the great transparency of these microscopic animals, their digestive sacs, when empty, or when filled only with water as they often are, appear like portions of the common cellular substance of the body, or like gemmules, or internal animalcules, and from not being easily or generally recognised as alimentary cavities, many, like Lamarck, were led to believe that these animals were without a mouth or any internal organs, and were nourished by superficial absorption, like marine plants. Lewenhoeck, however, observed that they possessed an internal cavity, and devoured each other; the same was seen by Ellis; Spallanzani perceived them swallowing each other so voraciously that their bodies became distended with their prey; and Goetze designated the *trichoda cimex* the wolf of infusions from its rapacity among the smaller animalcules. Gleichen placed animalcules in infusions coloured with carmine in order to discover the forms of their digestive cavities, and he has figured many *trichodæ*, *vorticellæ*, and

other animalcules with their internal sacs filled with this coloured matter; the same was done by Trembley; and these stomachs are figured by Müller, Bruguiere, and most others; but Müller supposed that they fed upon water, from their stomachs being most frequently filled with that fluid. Ehrenberg has more extensively employed opaque colouring matter to detect the forms of these internal cavities, and by using principally carmine, sap-green, and indigo, carefully freed from all impurities which might prevent their being swallowed, he has succeeded better than his predecessors in unfolding the structure of the digestive organs of animalcules. Such coloured organic matter, diffused as fine particles mechanically suspended in the water in which animalcules are placed, is readily swallowed by them, and renders visible, through their transparent bodies, the form and disposition of their alimentary cavities; but, however long they remain in these coloured infusions with their stomachs distended with the colouring matter, it is not perceived to communicate the slightest tinge to the general cellular tissue of their body. They appear to possess an acute sense of taste in rejecting coloured metallic and other substances which might prove hurtful to them, and their food appears to consist chiefly of smaller animals of the same class and of particles of mucus or other decomposed organic matter found in the water.

In most of the polygastric animalcules there is an alimentary canal, with an oral and an anal orifice, which traverses the body, and is provided with numerous small round cœcal appendices, which open into its parietes throughout its whole course, and which appear to perform the office of stomachs in receiving and preparing the food. In the simplest forms of animalcules, however, as in the *monas atomus* (Fig. 107. A.), there is but one general orifice (107. A. *b.*) to the alimentary cavities (107. A. *d.*), which is placed at the anterior extremity of the body and is surrounded with long vibratile cilia (107. A. *a*,) which serve both as organs of motion and tentacula. The several stomachs (A. *d.*) covered by the general wide integument, (A. *e.*) open by distinct short œsophageal canals (A. *c.*) into the common buccal orifice (A. *b.*), and there is no separate anal aperture for the excrementi-

FIG. 107.



tious residue of digestion. This simple form of digestive apparatus found in the monads appears to belong to about forty other genera of this class, which, from this circumstance of having no intestine passing through their body, have been formed into a group designated *anentera*. In the *monas termo* which is only about the two-thousandth of a line in diameter, four to six of these small round stomachs have been observed filled with colouring matter, although they did not appear to be half the number which might be contained in its body; each of these stomachs, of about the six-thousandth of a line in diameter, appears to open, as in other *anentera*, by a narrow neck into a wide funnel-shaped mouth, surrounded by a single row of long vibratile cilia, which attract the floating organic particles, or minuter invisible animalcules, as food. This anenterous form of the digestive apparatus, constituting almost the entire organization, is found both in the sheathed or loricated and in the naked forms, belonging to the lowest genera of this class, many of which, however, have been found to be only the young of supposed higher genera.

The intestine which traverses the interior of the body in all the higher forms of polygastrica, and communicates with all the internal stomachs, presents very different forms in

different genera. In the *vorticella citrina* (Fig. 107. B.) the intestine (*b, c, d, e.*) passes downwards without dilatation, and after bending round in the lower part of the body, it ascends more narrow to terminate at the same lateral oral funnel-shaped ciliated aperture (B. *a.*) at which it commenced, having numerous cœcal dilatations or stomachs (B. *f.*) communicating with its interior throughout its whole course. This circular form of intestine, opening at both its extremities in the same ciliated aperture, is perceived also in the *carchesium, zoocladium, ophrydium, vaginicola,* and other genera, which from this character form the group termed *cyclo-cœla*. In some animalcules of this group, as in the *stentor polymorphus*, (Fig. 107. C.), the circular intestine is regularly sacculated, or alternately dilated and contracted, throughout its whole course (C. *b, c, c, d.*), and from these dilated parts the little stomachs (C. *f.*) take their origin. In other species of *stentor* the intestine is twisted in a spiral manner throughout its circular course. Many of the polygastric animalcules which approach nearer to the helminthoid classes in the lengthened form of their body, have the mouth and anus placed, as in higher classes, at the opposite extremities of the trunk, as seen in the *enchelis pupa* (Fig. 107. D.), where the intestine, passing straight and cylindrical through the body, from the wide ciliated terminal mouth (D. *a.*), to the opposite dilated rectal termination (D. *b.*), gives off very numerous cœcal cavities (D. *f, f.*) along its whole course. Such animalcules form the group termed *ortho-cœla* from the straight course of the intestine. In others, however, as the *leucophrys patula* (Fig. 107. E.), the intestine passes in a spiral course through the short and broad trunk of the animalcule, giving off digestive cœca (E. *f.*) in all parts of its course, from its ciliated wide oral extremity (E. *a.*) to the saccular rectum (E. *b.*) at the opposite end, and such animalcules as present this spiral form of the alimentary canal compose the group of *campylo-cœla*, of which there appear to be few known genera. About thirty-five genera of polygastric animalcules appear to have an intestine of some form (*enterodela*), passing through their transparent body, and developing from its parietes minute globular cœca, which are regarded as stomachs, from the quickness with which the

food is conveyed into them, and from its not being accumulated or retained in any other part of the digestive apparatus. Nearly two hundred stomachs have been counted in a *paramœcium* and in an *aurelia*, filled with food at the same time, and there may have been many more, unseen from their empty and collapsed state. These digestive sacs are contracted filiform and almost invisible when empty, but they are susceptible of remarkable dilatation, and are sometimes seen distended with water, or smaller animalcules, or portions of confervæ swallowed as food; and the forms of these minuter animalcules can often be detected in the half-digested masses expelled from their posterior opening. Viewed through the microscope, the polygastric animalcules present very different appearances, according to the quantity and the kind of food contained in these digestive sacs, and from deceptions of this kind twelve different species of animalcules, belonging to six supposed distinct genera, have been formed of the single species *vorticella convallaria*. Although no muscular apparatus is perceptible in the transparent bodies of the polygastrica, distinct maxillary or dental organs are seen in many species belonging to very dissimilar genera. They consist of numerous long straight, stiff, elastic spines, disposed parallel to each other, and arranged so as to form an oral cylindrical proboscis, capable of being extended, widened, or contracted, to seize and compress the soft prey. No glandular organs to assist in digestion have been observed in this class of animals, notwithstanding their dental apparatus and the multiplied cavities of their alimentary canal. They are often observed to swallow animalcules nearly as large as themselves, and which could not be lodged in any of the digestive sacs; these appear to remain in the distended alimentary canal, and they render them, for a time, inactive. One polygastric animalcule often contains many hundreds of smaller prey within its body, and, notwithstanding the almost invisible minuteness of the animals of this class, and the great simplicity of their structure, they appear to be at once the most numerous, the most active, the most prolific, and the most voracious of all living beings. In some of the minutest forms of monads we are often unable to perceive any internal cavity; in others, from one to a very variable number of cavities are rendered visible by coloured food—an

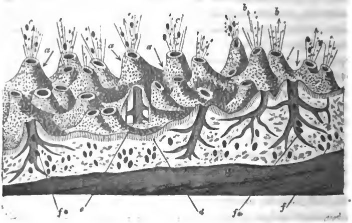
anenterous monad with a single cavity presents the simplest form of the digestive apparatus known among animals. In some of the larger *paramœcia* the food appears to move freely in round masses through the general internal cavity of the body, and these are sometimes accumulated at one end of the animal and sometimes at the other. The straight alimentary canal with its numerous lateral appendices in the *orthocœla,* approaches most nearly to that of many helminthoid articulata, as the halithea, the leech, and many inferior forms of annelida, rotifera, and entozoa. The opening of these cœca on the surface of the body, and changing the direction of the food's motion, would produce the form of alimentary organs presented by the poripherous animals.

II. *Poriphera.* The alimentary apparatus of poripherous animals, by the peculiarity of its form and the simplicity of its structure, approaches the nearest to that of plants; the cellular tissue of their body is permeated in all directions by ramifying and anastomosing canals, which begin by minute superficial pores closely distributed over every part, and terminate in larger orifices variously placed according to the exterior form of the entire animal. In the minute superficial absorbent pores we can generally perceive a fine transverse gelatinous net-work (Fig. 2. N.) and projecting spicula, to protect these entrances from the larger animalcules and from noxious particles floating in the water. The internal canals, like the veinous system, leading from capillaries to trunks, are bounded internally by a more condensed or more highly organised portion of the general cellular substance of the body, and are incessantly traversed by streams of water, passing inwards through the minute pores, and discharged through the larger orifices or vents; but no polypi have been observed in any of those parts, nor even cilia, although from analogy we may suppose them necessary as the active agents of the currents. In this simple organization there appears to be only an increased extent given to the general cutaneous absorbent surface; there are yet no distinct cœca or stomachs for receiving and retaining the aliment that has been conveyed into the body along with the currents of water. These animals in their earliest free and moving condition, while they are in the state of gemmules,

and for some time after their development in a fixed condition has commenced, present no perceptible canals or cavities of any kind in their body; nor do the polypipherous animals while they continue in the same free state of ciliated moving gemmules. As the development of the porifera proceeds, minute openings are observed to form on the surface, which extend gradually through the body, producing internal canals which terminate superficially in vents or fecal orifices. From the incessant currents conveyed through the body of these animals, it would appear that all parts of their interior, like the exterior surface, of their general cellular tissue, are adapted to admit by endosmose, and to assimilate nutritious matter to the texture of their body. On watching the streams of water that issue from the vents, minute flocculent particles are observed incessantly detached from the interior, and thrown out with the currents, these appear to be fine mucous pellicles excreted from the surface of the internal canals, as the residue of digestion thus detached from the body. A similar mode of excretion is often seen on the naked mucous surface of zoophytes, where thin pellicles are periodically detached from the soft exterior of the body.

In the spreading sessile species of porifera, as in the *halina papillaris* (Fig. 108.) so common on all parts of our coasts, both the small absorbent pores (108. *a*, *a*, *a*.) and the larger fecal vents (108. *b*, *b*.) are necessarily disposed on the same general external free surface, the inferior surface (108. *g*.) being fixed to the rocks or other sub-marine bodies and thereby completely closed. The upper free portion of the body, as in most other animals, is more appropriated to nutrition, and the lower or posterior part to generation. A vertical section of the body, shows the continuation of the pores (108. *d*.) which lead to the larger branches, canals (108. *e*.) and vents (108. *b*, *b*.). Along with the small portions of feculent matter (108. *b*. *b*.) are seen propelled from the vents numerous ovate reproductive gemmules (108. *c*. *c*.) after they have been developed in clusters (108. *f*.) in the deeper parts of the body, and have escaped into the internal canals (108. *f**. *f**.). In the tubular species, as in the *leuconia compressa* (Fig. 3.), the whole outer surface or periphery of the body is appropriated exclusively to the absorbent pores

Fig. 108.



which lead obliquely upwards through the parietes to the general internal cavity, and from this cavity the currents pass out by an inferior orifice (Fig. 3 *d.*), the upper part (Fig. 3. *c.*) in such forms being the closed part of attachment. The proper vents in such tubular species are therefore only seen upon opening the parietes and observing the inner surface (Fig. 3 *b.*) which is entirely covered with orifices of a larger size than the exterior pores. In the branched forms of poriphera, which, from the softness of their texture, appear always to hang downwards from their point of attachment, the whole outer surface is closely studded with minute pores, as in the *haliclona oculata* (Fig. 2 A. *a.*), and from these pores the anastomozing canals wind through the interior to open on the margins of the branches by wide prominent vents (Fig. 2 *b. b.*). The vents are disposed in all the different forms of porifera so as least to incommode the absorbent pores by the flocculi of matter constantly discharged from them with the currents. The vents are raised from the general absorbent surface to the ends of projecting papillæ (Fig. 108. *b. b. c. c.*) in those species which are attached to the acclivities of rocks; there

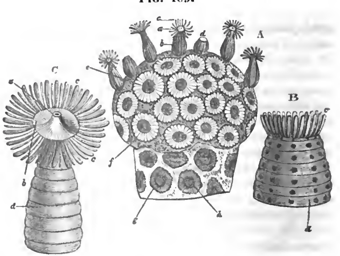
are no such papillæ on those which fix on the under surface; the vents open on the outer margins of the ramified forms (Fig. 2 *b. b.*), and they open into the interior of the tubular species (Fig. 3. *b.*), so as to be most free from the absorbent pores which would readily be obstructed by the mucous flocculi and particles of foreign matter propelled from the large orifices. The absorbent canals of poriphera are like the ramified roots of a plant turned inwards, and from the simplicity and similarity of their structure in every part they are susceptible of infinite division without destroying their vitality, and distinct individuals, by coming into contact in the progress of their growth, easily coalesce to form one mass.

III. *Polypiphera.* In the polypipherous animals or zoophytes the digestive organs are more distinct from the common cellular tissue of the body, and present a more complicated form than in the porifera, as the margins of the pores are here lengthened out to form little stomachs or *polypi*, organised to select, and seize, and digest living animalcules; parts of the lips of these polypi are also still further extended to form sensitive prehensile *tentacula*, and the sides of these tentacula develope numerous minute filiform *cilia*, by the rapid vibration of which currents are produced in the water to attract prey. In the *hydra* or fresh-water polype, the whole digestive apparatus consists of a simple sac, excavated in the cellular substance of the body, and destitute of all cœca or glandular appendices, and even of a distinct anus. The parietes of this simple polype appear to possess the same properties in every part, as they continue to seize and digest food when the animal is turned inside out, and each part of the animal, when cut to pieces, is found to develope itself to a perfect polype. What was formerly the internal digestive surface is found also to become the generative, and to produce gemmules and young polypes when the animal is turned inside out. They feed chiefly on larvæ and annelides which they search for and seize by the long tentacula developed from the sides of their mouth, and they often swallow animals many times larger than their own body, by stretching their thin elastic parietes over their prey. The digested part of the food passes through the common cellular tissue of their body, and through their tubular tentacula,

and the residue is thrown out by the mouth. In most of the soft flexible vaginated forms of zoophytes, or keratophytes, the posterior part of the polypus, which is the surface of attachment in the hydra, is perforated by a pyloric orifice to allow the digested part of the food to pass backward into the circulating system, as shown by Cavolini in *sertulariæ*, *plumulariæ*, *campanulariæ*, and most other forms. The polypi in those vaginated forms of keratophytes are the only parts of the fleshy substance of the body which come into free contact with the surrounding element, and they constitute highly irritable and sensitive sacs, the tentacula surrounding the margins of which are generally provided with vibratile cilia to produce currents, and attract prey within their grasp. The whole digestive and circulating cavities ramified through the body of these animals form an approach to those ramified through the common cellular substance of poriphera, but here there are no common vents or fecal orifices. From the transparency of the polypi and of their horny enveloping cells, we can easily perceive the contained food while it is being digested, and that the excrementitious residue is thrown out by the same orifice by which it entered, while the digested nutritious portion is successively transmitted backwards through the pyloric orifice, to be circulated through the central fleshy cavity pervading all the ramifications of the body. These movements of the digested matter through every part of the fleshy substance of keratophytes, appear to depend on internal vibratile cilia, as the movements of similar globules in the tubular fleshy feet of echinoderma, and in many other parts of radiated animals. The polypi of the *alcyonella* have a distinct lateral anal termination of their digestive canal, and they further approach to the *vorticellæ* in their double series of tentacula, which are here provided with vibratile cilia. The digestive polypi have a more complicated and isolated structure, in the *cellariæ* and *flustræ* as in the *flustra carbesia* (Fig. 63.), where the stiff elastic tentacula (63. *d.*) disposed in a campanulate form and furnished with vibratile cilia, are supported on a dilated portion of the body like a head, and where the alimentary cavity has not only a lengthened cylindrical curved intestinal form, but is even provided with a distinct cœcal or glandular appendix (63 *b.*) opening

into its posterior portion. This small cœcum, the rudiment of a liver, presents a continued revolution of the particles contained in it, and is sometimes seen to pulsate like a heart. It is smaller in the *flustra foliacea* where the lower curved part of the polypus is dilated into a wide gastric cavity. These polypi have also distinct bands passing from their body to the aperture and to the base of the cells, apparently to assist in their rising and retreating; the polypi appear to be capable of subsisting in an isolated condition, when detached from the cells to afford space for the development of the gemmules, as I have often found them swimming free in the water by the rapid contraction and extension of their tentacula. It is chiefly in the lowest zoophytes and in the smallest and simplest forms of polypi that the tentacula are furnished with vibratile cilia, as in *sertularia, plumularia, cellaria, flustra, alcyonium, alcyonella*; in some, as *campanularia* and *tubularia*, the cilia are disposed round the extensile lips, and the tentacula are simple; and in many higher forms of polypi, as in *madrepora, gorgonia*, and *lobularia*, where the cilia have generally a similar disposition around the mouth, the tentacula are furnished with lateral appendices which are not vibratile, and the stomach open at both ends, forms a separate internal sac, as in *actinia*, allowing the gemmules of each separate polypus to escape through this open passage. The large polypi are more nearly isolated in their condition in many of the massive lithophytes, as in the large deep-green polypi of the *astrea viridis* (Fig. 109. A. B. C.), where they are more than six lines in length, and protected in deep laminated polygonal cells (109. A. *g. h.*) two lines in diameter, they are striated with longitudinal (109. A. *b.*) and transverse (109. B. C. *d. d.*) bands, and are connected only by a thin fleshy layer (109. A. *f.*), covering the dark brown coral, and scarcely perceptible when the polypi are retracted into their cells (109. A. *e. f.*). The numerous bright-green tentacula (C. *c.*), alternately large and small, disposed around the very prominent blue mouth (C. *a.*) of the polypus, appear to constitute a double row of simple arms as in the *tubulariæ*, and the surface of the polypi in their contracted state is marked with regular vertical rows of prominent tubercles (B. *d.*). The polypi of *lobularia* are provided externally

FIG. 109.



with regular vertical series of dense white glistening calcareous spicula, attached to their parietes, and the internal cavities of these polypi are continuous with the long tubular radiating canals which traverse and almost constitute the entire fleshy mass of the body. The internal structure is very similar in *pennatulæ* and *virgulariæ*, where the mature free ciliated gemmules also pass out through the open cavity of the stomach. In many zoophytes, each polypus forms a separate animal, as in several *tubulariæ*, *caryophylliæ*, and *fungiæ* where the cells are as isolated as the polypi. The *caryophyllia cyathus* is composed of an isolated calcareous cell, containing a large polypus with a double row of conical tubular tentacula destitute of cilia or any kind of lateral appendices, and altogether constructed like an actinia in its digestive sac and its vertical ovarial partitions. In the winding superficial concavities of the *meandrinæ* is protected the variously-coloured fleshy mass of the animal, with numerous short conical polypiform orifices having generally eight marginal lobes, the remnants of the eight fimbriated short tentacula so common in the higher forms of zoophytes, and along the margins of the prominent calcareous ridges

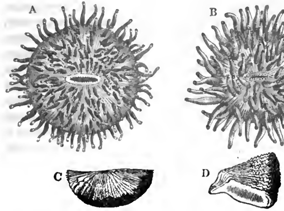
are seen numerous conical tubular fleshy tentacula, like the tubular feet of a holothuria. In the still deeper and more isolated concavities of the *pavoniæ* are found the large depressed expanded polypi, with eight-lobed orifices, and closely resembling the sea-anemonies in their exterior form and internal structure, as seen in the deep-green polypi of the

FIG. 110.

pavonia lactuca (Fig. 110. *a. a.*), from the shores of the South Sea Islands. The transparent, common, connecting, fleshy substance of these polypi, becomes a thin and almost imperceptible layer at its exterior margins, but rises, in the expanded condition of the animal, even beyond the extreme edges of the delicate calcareous foliated expansions (110. *c.*) which compose this elegant lithophyte, and thus extend their limits by the addition of calcareous matter. The eight short lobes (110. *b.*) of the oblong oral disc of these broad depressed polypi (110. *a. a.*), are the only traces of marginal tentacula which they present. The cavities containing the polypi are almost destitute of those vertical prominent sharp ridges and depressions, which mark both surfaces of the undulating

foliacious expansions, and which increase in depth towards their free elevated dentated edges (110. *c.*), and the numerous brown-coloured papillæ, spread over the yellowish-green surface of the polypi are the rudiments of the conical tubular feet so largely developed on many other lithophytes. From the magnitude and muscularity of the polypi in most of the larger forms of lithophytes, and from the increased number and strength of their prehensile organs, they are adapted for seizing and digesting more highly organized prey, than those delicate minute cellular forms which attract the smaller floating animals by vibrating the cilia of their tentacula. The most complicated forms of fixed polypi, and those which approach the nearest in structure to the free and independent *actiniæ*, are generally those which have the largest and most isolated cells, as we observe already in the prominent lips and internal partitions of the polypi of *tubulariæ*, and their double row of tentacula destitute of cilia. In the *caryophylliæ*, where the whole animal is sometimes composed of a single polypus with its cell, as in *caryophyllia cyathus*, the tentacula are not only disposed in a double series around the flat disk of the polypi, but are also short, thick, membranous and tubular as in most *actiniæ*, and ciliated internally like the tubular conical feet of most echinoderma, and the corresponding hollow organs of the higher zoophytes. In the *turbinolia*, likewise, which consists of a single conical calcareous cell with thin vertical radiating lamellæ, there is but one large actiniform polypus with a flat disk, a transverse oral aperture, and a sub-duplicate series of long tubular conical tentacula, disposed around the margin of the fleshy disk; the exterior surface of these tubular tentacula is sometimes irregularly tuberculated, like those of many inferior vaginiform zoophytes, and as we perceive in those of the simple *hydræ*. The polypi of *fungiæ* more closely resemble *actiniæ* than those of any other lithophyte, as seen in those of *fungia actiniformis* (Fig. 111. A.) and *fungia crassitentaculata* (Fig. 111. B.), from the South Pacific. In these broad expanded isolated polypi, enveloping a solid lamellated calcareous axis (111. D. C.), the transversely-elongated central mouth is lobed on the margin (111. A.), or surrounded with lively-coloured tubercles (111. B.), as in many actiniæ; and the whole surface of the fleshy

FIG. 111.

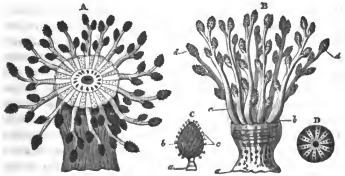


disk is covered with long muscular tubular conical prehensile tentacula, disposed irregularly, with minute terminal apertures, striated with transverse muscular bands, and protruded by the injection of water into them from below, like the tubuliform feet of echinoderma. In the *fungia actiniformis* (111. A. D.) the tentacula are very numerous, long, brown-coloured, slender, sub-cylindrical, and terminated by a yellow-coloured, dilated, perforated disk; the general surface of the polypus is yellowish-coloured with green striæ; the long, convoluted, white ovaries, like those of actiniæ, are protected between the vertical plates of the calcareous axis (111. D.); the flesh passes likewise over the inferior surface of the axis which is concave, and laminated on that part as above; and when the animal is alarmed the tentacula are withdrawn between the upper vertical lamellæ, the flesh shrinks downwards between these plates and is found accumulated chiefly on the under concave laminated surface of the axis. The tentacula are larger, fewer in number, more muscular, thick, and conical, in the *fungia crassitentaculata* (111. B. C.); they rise from a yellowish-coloured flesh covering the flat upper surface of the lamellated orbicular axis (111. C.); they are formed like leeches, striated transversely, of a brown colour, and terminate in a greenish-

yellow perforated disk capable of seizing and conveying to the central mouth of the polypus the smaller crustaceous or molluscous animals brought within their reach. The most complicated and most isolated forms of the polypi, or digestive sacs of zoophytes, are the free, locomotive *actiniæ*, destitute of a calcareous axis, and where the muscular and nervous systems, and the organs of digestion, generation, and respiration are already distinctly developed. Strong muscular bands surround the coriaceous external contractile covering of the body, and others extend vertically to the spreading flat base; a thick muscular sphincter, to enclose all the delicate parts of the disk, surrounds the upper and exterior margin, and another the entrance of the stomach; and numerous vertical muscular partitions, extending from the upper disk to the base of the *actinia*, and from the exterior skin inwards to the gastric cavity, divide this peripheral space, as in most of the higher zoophytes, into numerous genital compartments occupied by the long, white, convoluted, filiform ovaries, or gemmiparous sacs, attached to the inner free margin of membranous alternate folds extending inwards from the skin. The capacious stomach, provided with a muscular and mucous coat lined with vibratile cilia as in other zoophytes, and striated with vertical opaque bands and plicæ, occupies the axis of the body, and communicates as in other highly-organized polypi, with the genital cavities below. These lateral cavities between the stomach and the skin, communicate with each other, and with the numerous muscular conical tubular tentacula which are lined internally with vibratile cilia and are perforated at their free apex, like the tubular feet of higher radiata: so that every part of the *actiniæ* is capable of being bathed and distended with the surrounding element like a respiratory organ, and the stomach is easily protruded from the mouth by the distension of the genital cavities behind with that fluid. The *actinia*, like the *hydra*, free and unfettered by a solid axis, stretches its elastic body over prey many times larger than itself, and by the great digestive powers and copious secretions of its most capacious stomach, it quickly extracts nourishment from all kinds of animal substances, living or dead, which are brought within the reach of its adhesive poisonous secretions and its expanded tentacula by the ceaseless motions of the tide. The sand, gravel,

and broken shells, often swallowed with the food and found distending the stomach, are thrown out by the same oral aperture when the stomach is protruded. The margins of the oral disk, supporting the tentacula, are sometimes found extended in foliaceous expansions, and covered with minuter forms of these sensitive organs, by which the prehensile and respiratory surfaces are also increased in extent. In others the tentacula are tuberculated on the surface, or are lengthened and ramified with the luxuriance of many inferior *alcyonia*, or like the roots of a *rhizostoma*, or the radiating divisions of a *euryale*, as we see in the *actinia alcyonoidea* (Fig. 112. A. C.) and the *actinia arborea* (Fig. 112. B. D.),

Fig. 112.



two large species from the South Pacific. The cylindrical body of the *actinia alcyonoidea* (112. A.) striated longitudinally with numerous undulating brown-coloured bands, terminates above in a circular green disk spotted with deeper shades of the same hue, and presenting a lively rose-coloured oral aperture in the centre. From the outer margin of the disk sixteen large cylindrical ramified tentacula extend to the distance of half-a-foot from the mouth, and have all their divisions terminated by rasemose enlargements (112. C.) which are closely covered with minute pedunculated suckers (112. C. *b. c.*), by which the sensitive, the prehensile, and the respiratory surface of this remarkable zoophyte is greatly increased, and it is better enabled to perceive and to grasp larger prey floating or swimming freely through the

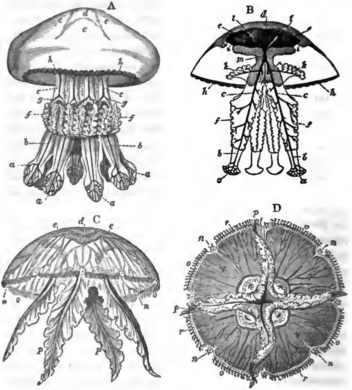
sea. The ramifications of the long, thick, and longitudinally striated tentacula of the *actinia arborea* (Fig. 112. B.) render that isolated polypus, which is more than a foot in height, still more dendritic in outward form than the last species; and the smaller size of its body (B. *a. b.*) makes it more nearly approach to the higher stellated echinoderma, as the *ophiura, comatula*, and *euryale*, where the nutritive organs are confined, as here, to a small central disk. The deep blue-coloured disk around the mouth (112. D.), between the thick bases of the ramified tentacula, is here also marked with numerous brown-coloured spots, regularly disposed on yellow bands radiating from the mouth to the margin of that surface, and the dichotomous character of the branched tentacula (112. B. *b. c.*) is seen even in the minute fleshy tubular filaments (B. *d. d.*) which cover the terminal tubercles of all the branches. The adhesive mucous exudation from the surface of all those ramified tentacula, as in other *actiniæ*, inflames and irritates the human skin, and may serve alike to seize and to destroy the victims which fall within their grasp. In the pedunculated form of the *lucernaria*, with its soft irritable body and central digestive simple sac like an *actinia*, and its connected radiating pedigerous divisions, we are also approximated to the condition of the higher stellated echinoderma, and especially to the pedunculated crinoid family, so that, from the simple isolated sac of the hydra, which is alike generative and digestive in every part, we pass through a great and most diversified series of zoophytic forms, to the complicated structure of these large independent actiniform polypi, where separate parts of the body are already distinctly appropriated to the most general and important functions of organic life.

IV. *Acalepha.* The soft transparent gelatinous *acalepha*, floating like large animalcules through the sea, are but free digestive cavities, like inverted zoophytes detached from their stony axis, and have their alimentary organs extended through every part of their mantle, their long filiform tentacula, and their pendent ramified peduncles. Among the ciliograde acalepha, the *beroë pileus* has a straight alimentary canal passing through the long axis of its body, commencing at the lower part with four thin prominent contractile and highly irritable lips surrounding the wide oral aperture. The contracted œsophageal part is

succeeded by a gastric expansion of this straight canal, containing frequently minute entomostracous crustacea which have been swallowed as food, and a narrow straight intestine terminates in a prominent anal orifice at the upper part of the body. The numerous ciliated canals conveying currents and globules through every part of the animal appear to be connected with the alimentary cavity, as in zoophytes and in other acalepha, and currents of water appear to flow through the alimentary canal in its empty state. In the *alcinoe vermiculata*, provided also with eight longitudinal bands of vibratile cilia, the alimentary canal passes straight through the axis of the body, surrounded below, at its oral entrance, as in *beroe*, with four prolonged marginal lips, but here of a lengthened conical form like the tentacula of polypi. Numerous cœcal prolongations from the cavity of the stomach are seen in *physalia* extending into the abdomen and are generally found to contain portions of the digested food. The digestive sacs of the *physophora* resemble the polypi of *companularia*, but destitute of tentacula, and their contractions are seen to aid the progressive motions of the animal in floating through the water, as the contractions of *medusæ* and of some *beroës* assist in their progression. The wide tubular proboscis in the centre of the lower surface of the *velella* (Fig. 6. 1.) leads to a capacious stomach occupying the middle part of the body, from which minute orifices appear to extend to the numerous small tubular suckers placed around the mouth; and the same structure is seen in the *porpita* where the digestive cavity, the only important system yet developed, is protected above, as in *velella*, by the firm internal skeleton. Around the delicate margin of the *berenice*, which was thought to be agastric, there are numerous prominent papillæ, the tubular passages of which lead to a wide central stomach. Most of the small physograde acalepha, as well as the larger pulmodrade medusaria, like inverted zoophytes torn from their fixed attachment and floating through the sea with their polypi extended in all directions, have numerous small pendent orifices at the extremities of peduncles more or less ramified and extended, and these polypiform mouths lead by narrow canals to a central sac, from which the nutritious matter is sent by numerous radiating ramified ducts to all parts of the body.

Larger and more direct openings, varying in number in different animals, are also generally observed leading into this gastric cavity, which is sometimes central and single, and in others is divided into compartments disposed around the vertical axis of the disk. From the transparency of every part of the body in the *rhizostoma Cuvieri* (Fig. 113. A. B.) the limits of the central gastric cavity (A. *d.*) and of the four surrounding ovarial sacs (A. *e. e. e. e.*) can be easily perceived through the thick parietes of the mantle, and also the numerous ramifications of wide vessels which extend from the circumference of this quadrangular stomach to the purple-coloured, lobed, highly vascular, and respiratory margin of the disk (A. B. *h. h.*). The peduncle hanging from the centre of the disk divides into eight branches (A. *c.*

FIG. 113.



c.), which terminate below in simple lobed dilatations (A. *a. a. a. a.*) having their surface marked with numerous depressions which are the orifices of internal canals (A. *a. b. c.*) leading upwards to the stomach. In the middle and upper parts of these eight branches there are fimbriated membranous extensions (A. *f.* B. *f. k.*) the numerous vessels of which also anstomose with the principal ascending trunk of each peduncle. On making a vertical section of this *rhizostome* through the centre of the disk (113. B.) we observe the internal canals (B. *b. c.*) commencing from the polypiform orifices of the branches (B. *a. a.*) receiving all the lateral absorbent or respiratory canals (B. *f. f. k. k.*) in their course, and uniting above to form one large œsophageal passage (B. *m.*) before entering the wide central gastric cavity (B. *d.*) There are more than twelve open pores, the polypiform orifices of these digestive tubes, perceptible on the lobed trilateral dilated base of each peduncle (A. B. *a. a.*) and the delicate mucous lining of all these digestive cavities can scarcely be detached from the general cellular tissue of the body which they traverse. Thin membranous partitions (B. *l. l.*) separate the cavity of the stomach (B. *d.*) from the four surrounding ovarial sacs (B. *e. e.*) which open externally by distinct apertures (B. *i. i.*) and sixteen canals radiate from the periphery of the stomach, dividing and anastomosing as they proceed towards the outer margin of the disk (B. *h. h*). The myriads of minute ramifying canals, anastomosing freely with each other, form a continuous complicated plexus around the free margin of the mantle, and spread extensively on the coloured lobes (B. *h. h.*) which bound its periphery, thus forming, as in the pteropods, a respiratory apparatus of the most active organ of locomotion. In many of the higher *medusæ*, as in the *medusa aurita* (Fig. 113. C. D.) the mouth is single and opens directly from the centre of the inferior surface of the mantle, into a capacious stomach from which numerous vessels radiate to a circular canal surrounding the margin of the disk. The mouth of the *medusa aurita* is of a quadrangular form, supported by four curved cartilaginous plates, from which are suspended four lengthened tapering lips or tentacula (C. D. *p. p.*) as we find on the sides of the mouth in most

conchiferous mollusca. On inverting the disk (D) we observe the short quadrangular œsophagus in the centre, leading to a capacious gastric cavity partially divided into four sacs (C. *d.*) and from each of these sacs numerous alimentary canals (D. *q. q. q. q*) radiate towards the margin of the mantle, ramifying with great regularity, but presenting few anastomoses compared with those of the rhizostomes. Around the lower part of the stomach are disposed the four ovarial sacs (D. *e. e. e. e*) containing the coloured ovaries, and opening externally each by a distinct aperture as in other medusæ. The inner surface of the stomach has a spotted follicular appearance, and this divided cavity is separated by a double membrane from the open ovarial sacs beneath. From around the margin of the stomach there come off sixteen canals, alternately simple and ramified, which end in the circular vessel (D. *r. r.*) passing round the margin, and by placing the living medusa in sea water tinged with indigo, the stomach (C. *d.*) the radiating vessels (D. *q. q. q. q.*) and the circular marginal canal (D. *r. r.*) are soon found filled with the blue coloured infusion while the rest of the animal remains colourless. A nervous circle is seen around the oral passage from which the long tentacula (C. D. *p. p.*) are suspended; another nervous cord accompanies the circular canal (D. *r. r*) around the free margin of the mantle which is fringed with a row of minute tentacula (D. *o. o.*) highly sensitive and in constant motion; the organs of vision (D. *n. n.*) are placed in the sight depressions around the free edge of the disk; and in the middle of each of the eight lobes of the mantle, between each pair of eyes, is seen the dilated anal termination of a simple excrementitious canal (C. D. *o. o. o. o.*) generally containing the indigestible remains of very minute articulated and molluscous animals, which are thrown out by these eight marginal ani on alarming the medusa. Currents of digested matter are seen moving through the radiating ciliated canals of medusæ, as in those of the ciliograde acalepha and the corresponding organs of other radiated classes. In the *carybdea marsupialis*, which was thought to be agastric, there is a central inferior oral aperture, surrounded by four short conical tentacula, the stomach is partially divided into four compartments, from each of which a canal extends to the free margin of the

mantle; these four radiating alimentary canals are continued down through the four long marginal tentacula which extend from the edge of the disk, and the parietes of the stomach appear to be already provided with ramified biliary follicles which pour their secretion into its cavity. From the remains of minute rotifera, crustacea, and mollusca, found in the alimentary cavities of the rhizostome forms of acalepha they appear to subsist on animal matter more highly organised than themselves, and already divided into very minute parts, so that they require neither masticating nor glandular organs to assist in digestion; but in the monostomatous species adapted for larger food, the cartilaginous parietes of the mouth may compress or divide the prey, and the biliary follicles aid in its assimilation.

V. *Echinoderma*. The structure of the digestive organs in these fixed or slow-moving, thick-skinned, predaceous animals is as various as their outward form and their living habits, and presents the links of transition from the broad and radiated alimentary cavity of the acalepha to the long cylindrical narrow intestinal canal common to the articulated classes. In many of the stellated echinoderma, as the *euryale*, the *ophiura*, and the *asterias*, we observe a simple sac with one orifice, as in the *hydra* and the simplest polypi of zoophytes; in others, as the *comatula* and *encrinus*, the digestive canal is more lengthened and curves upon itself, as in *alcyonella* and *flustra*, and has an anal opening distinct from the mouth; and in the echinida and holothurida there is a long narrow convoluted intestine passing through the body, with as little gastric enlargement as in the long straight intestine of a worm. But in these various forms of echinoderma the digestive cavity is always bounded by parietes distinct from the common integument of the body, as in all the higher classes of animals, and is generally connected with them by means of a highly vascular mesentery. The mouth of the *asterias*, surrounded with long tubular tentacula and protected by fasciculi of calcareous spines, is situate, as in most cyclo-neurose animals, in the centre of the inferior surface of the body, and by a short œsophagus leads to a wide and most dilatable stomach provided with a distinct internal mucous lining and an exterior muscular tunic, and occupying the whole central

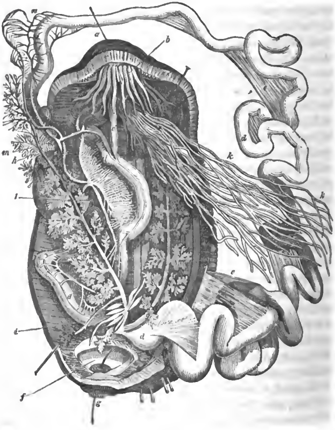
part of the body from which the marginal divisions originate. In the *ophiura* and *euryale* the digestive sac, with its ten small rudimentary cœca, are entirely confined to the central disk, but in the *asterias* two long tapering ramified cœca, like the biliary follicles of higher classes, commencing by a single trunk, extend from the stomach to a very variable length into each division of the body. Each of these ramified cœca of the asterias is attached to the integument along the upper part of the ray by a delicate vascular membrane, and its lateral ramifications terminate in small vesicular enlargements generally filled with digestive matter, or the secretion of their own parietes. The stomach is also furnished with small short cœca at its upper part within the disk, and at its sides between the great cœcal trunks of the rays, which likewise vary much in their forms and dimensions in different species. Above the stomach and towards the side is situated the small glandular sac covered externally with a solid calcareous plate and containing numerous minute crystalline calcareous spicula. In the *comatula* there is a distinct gastric cavity, and an alimentary canal long and cylindrical, forming two convolutions round the stomach in the central disk or abdomen, and open at its anal extremity. The mouth forms a large circular aperture towards one side of the centre of the inferior surface, and a small submarginal anus is seen at the opposite side, not far from the mouth, and opening at the end of a prominent papilla. The same structure of the alimentary cavity with its two distinct and approximated openings is seen in the *pentacrinus*, and it appears to have been the common form of the digestive canal in that great and almost extinct family of crinoid animals.

The mouth becomes furnished with strong masticating and salivary organs in the higher forms of echinida; and while it preserves its central position on the lower or anterior surface of the body, the anal orifice leaves that surface to assume a diagonally opposite position in the centre of the upper or posterior part, which prepares the structure for the lengthened horizontal forms of the holothurida and the articulated classes of animals where the axis of the trunk ceases to preserve the vertical position so general in the radiata. In the *scutellum* and the *clypeaster* both orifices still preserve the

inferior surface, the anal aperture has acquired a sub-dorsal aspect in the *spatangus* and many of the genera now extinct, and in the *cidaris* and *echinus* the mouth and anus occupy the opposite poles of a vertical axis. In the *spatangus*, which burrows in the moist sands and passes that substance constantly through its body in order to derive nourishment from the innumerable minute animals contained in it, the mouth, destitute of teeth and furnished with numerous long tubular tentacula, is placed on the lower flat surface towards the obliterated ambulacrum, and leads to a long convoluted black-coloured delicate alimentary canal which performs two revolutions in opposite directions, attached by a thin vascular mesentery to the upper part of the shell, and terminates at the marginal aperture on the posterior part of the body. The slight gastric enlargement at the commencement of this long intestine receives the opening of a single lengthened hepatic follicle or cœcum. The mouth of the *echinus*, which subsists chiefly on young mollusca and crustacea, is provided with a strong dental apparatus (Fig. 8. 2. 3.) embracing the commencement of the œsophagus, and is surrounded with delicate fimbriated contractile lips and numerous long tubular tentacula. The intestine, with a slight gastric dilatation and of variable diameter in its course, forms a double convolution in a waved direction round the axis, and is attached by a short vascular mesentery, containing minute tubercles like glands, to the interior of the shell. The anal aperture, at the upper pole of the vertical axis, is surrounded by a membranous expansion, sometimes with valvular folds, and is provided, like the mouth, with circular and radiating muscular bands for its contraction and dilatation. The structure is nearly the same in the *cidares* which present the most globular forms of the echinida, but the forms of the slight saccular enlargements in the course of the alimentary canal, and the zig-zag manner in which the intestine ascends and descends in performing its revolutions round the axis, vary much in the different species of *cidaris* and *echinus*. In its general conformation the *holothuria* is like a lengthened *echinus* deprived of its calcareous plates, and with the axis of the trunk extended in a horizontal direction. The mouth and anus are placed at opposite ends of the body, with a long convoluted alimentary canal, almost destitute of gastric

cavity, and connected to the sides of the abdomen by a vascular mesentery, passing from the one aperture to the other, as seen in the annexed figure of the *holothuria elegans* (Fig. 114.) by W. Bell. The mouth (114. *a.*) is generally surrounded with long tentacula in form of ramose tufts (*holothuria* of Lam.) in others the tentacula are simple, and expand only at their free ends (*fistularia* of Lam.), and sometimes long salivary follicles (*b.*) open into its parietes. The tentacula, capable of complete retraction within the oral aperture, are supported by the circle of osseous plates to which the strong longitudinal muscular bands of the trunk are

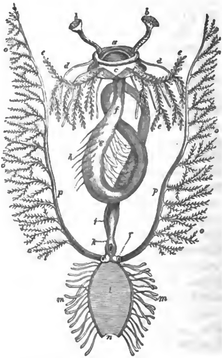
FIG. 114.



also attached. The œsophagus leads to a slightly enlarged gastric portion (114. *b. d.*) of the intestine, which receives the secretion of a large biliary follicle (114. *c.*) The intestine is generally filled with sand and comminuted shells, and the *holothuriæ* commonly lie among the ejectamenta of the sea where they appear to partake of a very mixed and heterogeneous kind of food. The whole surface of their body is traversed by longitudinal rows of long fleshy tubular feet for progressive motion and to secure attachment; and on the lower surface, near the anterior extremity of the trunk, is the common opening of all the divisions of the ovary (114. *k. k.*) as in many of the entozoa and annelida. The tentacula, like the tubular suckers along the body, are protruded by the injection of a fluid into them from their base. The long convoluted intestine (114. *d. d.*) passes backwards along the whole extent of the abdomen, then returns to near the mouth, and again turns backwards to terminate in the middle of the cloaca (114, *f.*), connected along this course, by a short delicate vascular mesentery (114. *e. e.*) to the sides of the trunk. The two long ramified tubular branchiæ (114. *h.*) terminate in the cloaca by separate orifices on each side of the rectal extremity of the intestine; after receiving the orifices of several small follicles (114. *i.*). A mucous, a muscular, and a peritoneal coat can be detected on the delicate intestine of the *holothuriæ*, as in several other echinoderma. The nutritious part of the food is taken from the intestine by the mesenteric veins (114. *l.*) and conveyed, with the venous blood of the system, to the long ramified internal branchiæ (114. *h. h.*), from which it is again collected by the branchial veins (114. *m.*) to be distributed through the great systemic arteries without the aid of a heart. As the cloaca (114, *f.*) is a capacious cavity which inhales the water to be sent through the tubular ramified gills (114. *h. h.*), the rectal portion of the intestine (114. *d.*) is protruded through that cavity to the external opening of the anus (114. *g.*) in evacuating its shelly contents, as in the oviparous vertebrata. The whole digestive apparatus of the *holothuriæ* are often forced out from the body, through the mouth, by the contractions of the strong muscular parietes of the abdomen, before death, and I have found even the dental plates and their attached tentacula,

protruded with the intestines in such circumstances. The mucous coat of the intestine, near its commencement, sometimes presents internal longitudinal plicæ. The alimentary canal is most variable in its extent and convolutions in different species of *holothuriæ*, and also the forms of their dental plates, according to the nature of their food. In the *holothuria ananas* (Fig. 115) which is nearly two

Fig. 115.



feet long, found in the South Sea, and prized as an article of food in the Molucca islands, there are twenty long pedunculated tentacula (115. *b. b.*) around the mouth (115. *a.*) which terminate each in a concave disk, embracing numerous red-coloured tubercles. The tubular fleshy feet here cover irregularly the delicate inferior or ventral surface of the abdomen; and those of the upper coriaceous surface

of the animal, having a flat foliaceous tapering form, are disposed like imbricated scales, and are perforated like the abdominal feet. Numerous long salivary follicles (115. *d. d.*) pour their colourless secretion into the mouth, and near them are placed the two long ramified coloured ovaries (115. *e. e.*) as in other holothuriæ. From the dental apparatus, surrounded by the muscular parts and integuments of the mouth (115. *a. c.*), the narrow œsophagus (115. *f.*) leads to a capacious and lengthened stomach (115. *g.*) with numerous vessels (115. *h.*) extending from its parietes along the reticulate mesentery. The intestinal canal (115. *f. g. i.*) which in some species is more than ten times the length of the whole body, is here only about twice that length, and was found turgid with sand. The rectum 115. *k.*) with strong parietes, terminates at the upper part of a long cloaca (115. *l.*) which is supported by numerous lateral bands (115. *m. m.*) and presents on its two sides the wide orifices (115. *r.*) of the long ramified arborescent branchiæ (115. *p. p. o. o.*) which ascend as high as the mouth. The anal opening (115. *n.*) of the cloaca, and the orifices (115. *r.*) of the two gills, are here so wide and so constantly open, that crustacea more than a quarter of an inch in diameter, were found living and residing in these passages, and this active cloaca was found to retain its high irritability after the animal had been cut to pieces. The dental organs, so powerful and complicated in the *cidaris* and *echinus*, and so variable in their extent of development in the *holothuriæ* and *fistulariæ*, have lost their calcareous matter in the *priapulus*, and are wanting in the long vermiform *sipunculi* which present a lengthened retractile tuberculated head, a wide funnel-shaped œsophagus, and a convoluted alimentary canal many times the length of the body, destitute of gastric dilatation, furnished with a few biliary follicles, and returning from behind to open externally near the mouth. Thus the digestive cavity, from the condition of a simple monostome sac, filling the whole abdomen, in the lower stellated forms of these animals, has gradually acquired the form of an elongated tubular narrow canal, open at both ends, and furnished with biliary and salivary follicles, in the helminthoid echinoderma, as in many helminthoid articulata.

THIRD SECTION.

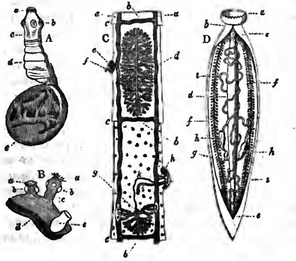
Digestive Organs of the Diplo-neurose or Articulated Classes.

The lengthened cylindrical and articulated form of the body in the helminthoid and entomoid classes, is that best suited for the creeping, piercing, parasitic and carnivorous habits, so characteristic of this great division of the animal kingdom, and the internal organs of these animals, especially the digestive, partake of this straight and extended form of the trunk. In the radiated animals, which are almost all stomach, the shortness and the vertical position of the axis, and the lateral expansion of the alimentary cavity, often enable them to dispense with a second orifice to their digestive sac, and better adapt them for seizing and swallowing entire the smaller animals so numerously spread through the waters of the globe. The carnivorous character, so general in the articulated classes, and even the highly organized condition of their prey, are indicated by the limited capacity and by the short and straight course of their alimentary canal, which almost universally opens at the two opposite extremities of the body, and by the numerous prehensile and destructive instruments so commonly placed at its commencement. As they are nearly all free animals, with power of rapid locomotion, and with a relatively high development of their nervous system and of their organs of sense, they are well adapted by their instincts and their organs of animal life to administer to the vegetative, by distinguishing and overtaking the most suitable and highly organized prey. As the simple and straight form is a character impressed upon the alimentary canal of the articulata, both by the narrow cylindrical form of the trunk and by their predaceous habits, we observe greater uniformity in its plan of structure than in the other divisions of the animal kingdom, although the endless modifications of their organs of relation enable them to seek their prey in every element and in every situation. The mouth is here generally provided with masticating

organs which move laterally and are provided with palpi; and hard parts subservient to this function are often found in the cavity of the stomach. The mucous lining of the alimentary canal exhibits few developments of villi, folds, or follicles, the salivary and pancreatic glands are rarely perceptible, and the liver has generally the simplest follicular form.

VI. *Entozoa.* The entozoa, subsisting on the living fluids of animals more highly organized than themselves, present generally the simplest condition of the alimentary apparatus met with in the articulated classes, and from the facility of assimilating the nutritious fluids which they absorb, many of these animals dispense with a separate anal orifice, and their digestive organs are thus often closely approximated in form to the vascular or sanguiferous system. In the cystoid forms of intestinal worms, as in the simplest polypi, there is only a buccal entrance to the digestive sac, and that orifice is often numerously repeated on the same sac, like the polypi of a zoophyte or the absorbent orifices of a rhizostome. In the hydatids, as in the hydræ, there is a simple digestive cavity destitute of an anal aperture, but here, as seen in the *cysticercus longicollis* (Fig. 116, A.), the buccal apparatus (A. *a. b. c.*), is in form

FIG. 116.



of a small white prominent head or papilla terminated anteriorly with a double row of minute, sharp, conical recurved spines (A. *a.*), and presenting around its sides four circular absorbent orifices (A. *b.*) From these orifices (A. *b.*) the absorbed fluids are conveyed by four slender canals through a narrow neck (A. *c.*) into a thin transparent white membranous sac (A. *d. e.*) more or less distended or contracted, according to the state of repletion, and according to the peculiar forms of the species. In the collapsed state of this digestive bag, its anterior part (A. *d.*) assumes a narrow, elongated, and corrugated form, and becomes more dense, white, and opaque, with numerous transverse constrictions which give it already an articulated appearance. A more compound zoophytic form is seen in the *cœnurus* where numerous minute heads, similarly constructed to those of the *cysticercus*, open into the same common digestive sac or vesicle. These heads are disposed in numerous groups over the surface of a large transparent gastric cavity, and appear as clusters of opaque white points. A small detached portion of the general digestive sac of the *cœnurus cerebralis*, highly magnified, and with three of the absorbent heads preserved in different states of extension, is seen in Fig. 116 B. The anterior terminal papilla of each head is surrounded, as in the *cysticercus*, with a double row of recurved spines (B. *a. a.*), and around the dilated part of the head are the usual four perforated suctorial disks (B. *b. b.*) The head is attached to a narrow neck (B. *c. c.*), capable of considerable elongation and contraction, and these passages all lead to the same capacious general digestive vesicle (B. *d.*) In the long flat cestoid forms of parenchymatous entozoa, the structure of the head, with its absorbent pores, is very similar to that of the hydatids. Around the anterior median papilla of the *tænia*, which is sometimes perforated with a small pore, there is a double range of minute recurved sharp spines, and the four lateral perforated suckers, disposed on the four angles of the head, lead to as many canals, as in the *cysticercus*. The upper and lower canal however on each side unite with each other to form one, and these two lateral canals, thus constituted of the original four, extend along the two sides of all the segments of the body, as seen in two of the segments magnified of the *tænia*

solium (Fig. 116. C. *a. a.*) These lateral digestive and contractile tubes communicate with each other by a transverse branch (C. *c. c. c.*) at the lower end of each segment where they are constricted and valvular, and they open externally by one or more lateral orifices (116. C. *h.*) on the sides of each division of the body. The dendritic ramifications of the ovary (C. *d.*) occupy the central part of each segment, and open externally beside the intestinal pore (C. *h.*), by a small distinct genital orifice (C. *i.*), from which likewise extends a styliform tubular duct (C. *k.*) considered as a male organ (C. *f.*) Besides the delicate exterior skin covering all these organs, there is an outer transverse and an inner longitudinal layer of muscular fibres which produce the varied movements of this aggregate animal, so that each segment of the tænia, which worm often exceeds a hundred feet in length, possesses all the requisite organs for nutrition and generation, as an entire animal, and no gastric enlargement is developed in the whole course of this alimentary tube. The four œsophageal canals however, of the *tænea dispar*, descending from the four lateral cephalic pores, unite together in the middle of the neck to form one median canal, which enlarges in each division of the animal, and passes thus sacculated and continuous, through all the segments of the body. Besides the usual lateral pores of the head a minute opening and canal are seen in the apex of the prominent papilla in the middle of the head of the *bothryocephali*, as in some of the *tæniæ*. The alimentary organs of the trematode worms are more ramified and sanguiferous in their appearance than those of the cestoid entozoa; they commence by one or more orifices near the anterior part of the trunk, and pass backwards ramifying and anastomosing freely along the lateral parts of the body, destitute of an anal opening, as in the other parenchymatous species. In the *distoma hepaticum* they form two parallel trunks near the middle of the body, and ramify into minute capillaries on the lateral parts, as they proceed tapering backwards to the posterior extremity of the animal. In the *pentastoma* they unite to form a single straight median canal in the back part of the body; so that we still observe the tendency to form a simple longitudinal median canal in all these forms of parenchymatous entozoa, as in the higher orders of this

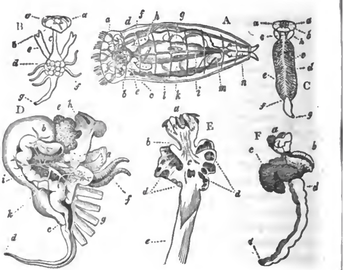
class, and in the higher forms of articulata. The *distoma hepaticum* is like a more highly organized segment of a *tænia*, in which we perceive a broad funnel-shaped œsophagus leading to two wide ramified alimentary canals occupying the middle part of the body, while the ovaries here occupy the sides, and two parallel ventral nervous filaments unite below the œsophagus and ramify as they extend around that wide passage. In the *echinorhynchus* there is a minute pore in the centre of the armed head, which leads to a single alimentary canal extending along the middle of the trunk and dividing, before it terminates, as in the other parenchymatous worms.

In all the nematoid and more perfect forms of entozoa the alimentary canal passes simple through the body, presenting a distinct oral and anal aperture which are generally at the opposite ends of the trunk, as in the higher articulata. The *ascaris*, like the other nematoid worms, has a single oral aperture at the anterior extremity of the body; the three marginal lobes of the mouth are provided with minute teeth and moved by distinct muscles, so that the mouth somewhat resembles that of the leech in its masticating apparatus. The œsophagus forms a wide elongated muscular sac, like that seen in the *halithea* and some other annelides; it is contracted at its lower part, and opens into a straight and wide intestinal canal with thin parietes, and where the limits of the stomach are seldom indicated by an inferior constriction. The digestive canal passes straight through the middle of the trunk, surrounded by the tubular windings of the testicle or ovaries, to the posterior extremity where it opens by a small traverse aperture on the inferior surface. In the *strongylus armatus* (Fig 116. D.) the hemispherical disk of the head is surrounded by dense, sharp, vertical teeth (D. *a*.), and the short œsophagus (D. *c*.) opens into a wide intestine (D. *d*.) without a distinct gastric portion and continued straight through the trunk to the anus (D. *e*.) at the opposite end of the body. The two long convoluted ovaries (D. *h*. *h*.) wind round the alimentary canal in its whole course through the trunk in the female, and unite to form a single vaginal orifice (D. *g*.) below the middle of the body, the single tubular testicle winds round the intestine in the same manner in the male, and opens by a long projecting hollow styliform organ of intromission at the posterior end of the

body. The straight and wide intestine of the *strongylus gigas* appears to be surrounded with short biliary follicles during the greater part of its course through the body. In the highest animals of this class, as the *achtheres, lernæa, peniculus, tracheliastes, brachiella* and *chondracanthus*, which have a more entomoid form, and suck the vital fluids from the delicate exterior parts of the skin of aquatic animals, the mouth is already provided with small lateral unciform mandibles, adapted to tear the surface to which the animals are fixed ; and their alimentary canal, wide and short and with a terminal anal aperture passes straight through the body, surrounded by the biliary follicles and by the genetal organs, as in higher articulated classes.

VII. *Rotifera.* In the minute and transparent bodies of the wheel-animalcules we observe the digestive, like the other organic systems, to present the typical forms of the articulated animals. Their large transverse maxillæ (Fig. 12.) are moved by a powerful muscular apparatus (Fig. 11. *b.*) and appear in incessant action while they are surrounded by minuter animalcules. Their carnivorous character is seen alike in the living and mangled contents of their transparent stomach (Fig. 11. *h.*), and in the short and straight course of their alimentary canal (Fig. 82. B). The alimentary cavity in some, as the *hydatina senta* (Fig. 117. A.) passes straight, simple, and uniform from the narrow œsophagus (117. A. *f.*) to its posterior cloacal termination, without any perceptible lateral cœca or follicles. They pursue their prey by vibrating the anterior circles of cilia (117. A. *a.*) by the muscular lobes at their base which are attached to ligamentous bands (117. A. *b.*) The large cerebral ganglion (117. A. *c.*) and the smaller lateral ganglia (117. A. *d.*) surround the strong muscular pharynx (117. A. *e.*) which is capable of being protruded and retracted to a great extent and with great rapidity. The living animalcules (117. A. *g.*) contained in the stomach are easily perceived, and the whole internal structure, through the hyaline texture of their body, and small glandular sacs (117. A. *h.*) are seen at the sides of the œsophagus (117. A. *f.*) which appear to send ducts to the muscular pharynx (117. A. *e.*) embracing the masticating organs. The dorsal vessel (117. A. *i.*) extends along the middle of the back, sending off numerous lateral branches in its course

FIG. 117.



forwards, and the sides of the abdominal cavity are occupied chiefly by the large lobed sacs of the ovaries (117. A. *k.*) and the long winding glandular sacs, considered as testicles (117. A. *l.*), which terminate behind the cloaca in a small vesicle like a vesicula seminalis (117. A. *m.*) Their food is often brought from a distance by vibrating their anterior cilia while their body is attached to some motionless surface by the two long terminal fleshy retractile peduncles (117. A. *n.*) In some, as the *stephanoceros*, the food is collected in a large buccal cavity, anterior to the maxillæ and behind the tentaculiform ciliated arms, before it is submitted part by part to the act of mastication. The gastric portion of the alimentary canal varies much in its form in different rotiferous animalcules. In the *diglena, enteroplea, synchaeta,* and *brachionus,* it presents a less uniform and more globular form than in the *hydatina* (Fig. 82. B.) In the *diglena lacustris* (Fig. 117. B.) the sharp pointed maxillæ (117. B. *a.*) and their muscular apparatus (117. B. *b.*) are succeeded by a lengthened and narrow œsophagus (117. A. *c.*) which opens into a short defined globular stomach (117. B. *d.*) From different parts of the

stomach two large (117. B. *e.*) and five small (117. B. *f.*) elongated cœca arisc, which appear like hepatic or glandular follicles, and do not admit into their interior the larger undivided portions of the food contained in the general gastric cavity (117. B. *d.*) From the pylorus, the intestine continues downwards, narrow and nearly straight, to terminate (117. B. *g.*) in the cloacal opening at the posterior end of the body, close to the two fleshy peduncles. The whole alimentary canal, from the mouth to near the anus, is narrow and cylindrical in the *rotifer vulgaris*, and follows a slightly winding spiral course through the body, closely surrounded with large, short, biliary follicles. At its rectal termination, however, it suddenly enlarges to form a wide globular colon. The same structure, nearly. is seen in the alimentary cavity of the *philodina roseola* (Fig. 117. C.) where the maxillæ (117. C. *a. a.*) and their muscular apparatus (117. C. *b.*) and the two pharyngeal sacs or glands (117. C. *h.*) are succeeded by a narrow and straight œsophagus (117. C. *c.*) and intestine (117. C. *d.*) The narrow intestine is closely surrounded by innumerable short straight biliary follicles (117. C. *e. e.*) or glandular cœca, throughout its whole course from the œsophagus (117. C. *c.*) to the short dilated colon (117. C. *f.*) which opens by its rectal orifice (117. C. *g.*) into the cloaca where the genital organs also terminate, as in most of the higher articulata. The lower part of the intestine is slightly curved upwards upon itself, so as to lengthen its course, in the *brachionus urceolaris* and *pterodina patina.* The stomach and the whole alimentary canal of the rotiferous animalcules move freely and loosely backwards and forwards, to a great extent in the wide and ciliated cavity of the abdomen, during the contractions of the long, slender, transparent muscles which extend longitudinally from the anterior end of the body, and the two glandular pharyngeal sacs of very variable form accompany them in their motions to and fro. The whole cavity of the abdomen, as well as the wide cavity of the intestine, in these transparent and colourless animals, appear generally as if distended with pure water, and vibratile cilia appear to be in rapid action both on the mucous and the peritoneal coats of the alimentary canal.

VIII. *Cirrhopoda.* The masticating and digestive apparatus of the cirrhopods present the same close affinities to

those of the articulated classes which we observe in the external form of their body, and in all their organs of relation. The mouth, as seen in the *pentalasmis* (Fig. 117. D. E. F. *a. a. a.*), provided with serrated mandibles which move transversely, and with a pair of maxillæ with rudimentary palpi attached to them, opens by a short contracted œsophagus (117. E. *b.*) with longitudinal internal folds, into a capacious sacculated stomach (117. E. *c.*) furnished with two large cœcal appendices and closely surrounded by the numerous small lobes of the liver (117. F. *c.*) Two distinct lobulated salivary glands (117. D. *h.* F. *b.*) pour their secretion into the mouth, and the numerous small compacted lobes of the liver (117. D. *e.* F. *c.*) open freely by short ducts with wide orifices (117. E. *d. d.*) into the cavity of the stomach, as in most invertebrated classes. From the contracted pyloric orifice of the stomach, the wide and corrugated intestine (117. D. *b. c.* E. *e.* F. *d. d.*) passes along the dorsal convex part of the body, presenting an annulated appearance, and having a distinct muscular coat of transverse fibres and longitudinal bands, but without convolutions or a distinct mesentery. The concavity left on the fore part of the body, by this wide curved intestine, which follows the course of the closed posterior portion of the shell (Fig. 13. *i. e.*), is occupied chiefly with the mass of the ovary (117. D. *k.*) and the wide oviduct (117. D. *i.*) surrounded with the testicle. The rectal portion of the intestine (117. D. *c.* F. *d.*) opens, along with the oviduct, into the base of the long capillated muscular tubular proboscis (117. D. *c. d.*), by which the residue of digestion is conveyed freely from the interior of the shell to which the animal is fixed. The food is brought within the cavity of the mantle, and within the reach of the three pairs of maxillæ, by means of the respiratory currents and by the incessant movements of the long curled ciliated feet, and it appears to be recognized by the palpi, the upper and lower lip, and rudimentary antennæ, without the aid of organs of vision which are here obliterated in the fixed adult animals, as they are in the fixed adult state of the epizoa. By the lobulated or conglomerate form, and the great development of the biliary and salivary glands, and by the numerous wide ducts hy which the liver communicates with the cavity of the stomach, the cirrhopods

are allied to the molluscous classes, which they also resemble in their fixed condition and their testaceous covering, in the adult state.

IX. *Annelida.* Notwithstanding the difference in the forms, habits and food of the annelides, there is great similarity in the structure of their digestive organs, which generally pass straight through their elongated body, with the mouth and anus at the opposite ends, with slight gastric dilatations in their course, and with an imperfect development of the hepatic and salivary glands. This simple condition of the alimentary canal, accords with the animal nature of their food; but as that food is received in various conditions, sometimes mixed in minute particles with earth or sand, and sometimes consisting of larger animals, there is greater diversity in the masticating organs which, in some of the higher annelides are numerous and complicated in structure, and in others are altogether wanting as in the earth-worms and many of the tubicolous species. The masticating organs generally consist of numerous pairs of lateral superimposed horny unciform maxillæ as in higher articulated classes; but in those provided with a sucking organ, as the *leech*, the mouth is furnished with numerous approximated, hard, sharp, recurved teeth, like those common in the molluscous classes. In some, as the *earth-worm*, the mouth presents a distinct upper and lower lip, as in the entomoid classes, and in others as the *phyllodoce* the interior of the mouth is capable of being protruded in form of a large proboscis or like the head of a sipunculus. The wide and capacious mouth of the earth-worm (Fig. 82. D. *a.*) is furnished with a large upper and a smaller lower lip, soft, fleshy, and of great sensibility, and a small salivary gland, and leads by a narrow œsophageal portion of the canal to a slightly enlarged sacculated stomach, consisting of three continuous cavities, placed immediately behind the genetal organs, about a third from the anterior end of the body. The second of these muscular digestive cavities is lined with a tough coriaceous easily detached coat to protect it from the earthy matter taken in with the food. The stomach opens into a narrower part of the intestine which continues along the middle of the trunk (82. D. *a. b. b.*) slightly tortuous in its course, and gradually enlarging as it descends

to the anus, where distinct levator and sphincter muscles are perceptible. The exterior of this intestinal portion, from the stomach to near the anus, is surrounded with small short biliary follicles, generally filled with their yellowish-brown coloured secretion. The whole alimentary canal of this animal is commonly found filled with the moist black earthy soil in which it lives, and which it incessantly conveys through its body to derive nourishment from the organized particles so abundant in that matter. The alimentary canal is more tortuous in its course, more capacious throughout, with its gastric portion less distinctly marked, in the delicate transparent short body of the *pectinaria*, and even in the long distensible trunk of the *arenicola*, which, like many other worms and echinoderma, transmit incessantly the moist sands of the sea through their intestine, to extract as food the innumerable minute animals contained in that medium. The coriaceous lining is seen in the lower portion of the more lengthened stomach of the *arenicola*, as in the earth-worm; and below this part are the openings of two yellow-coloured biliary follicles, lengthened in form like those of insects. Within the muscular sucking disk of the mouth, in the *medicinal leech*, there are three crescentic horny jaws, supporting each a row of sharp acuminated teeth, with which it files its triradiate wound. The intestine passes straight through the long axis of the body, sacculated in a regular manner, and furnished with short wide lateral cœca, nearly throughout its whole course. There are ten of these cœca on each side, and smaller enlargements of the intestine are interposed between each pair; the cœca increase gradually in size from the first or anterior to the ninth pair; and the two posterior cœca, which are much larger than any of the others, extend backwards along sides of the remaining short portion of the intestine. This sacculated part of the intestine occupies about two thirds of its whole length, and terminates, like a stomach, in the succeeding straight portion, by a narrow elongated valvular pylorus. The short and wide œsophagus is marked internally with longitudinal plicæ of its mucous coat, and the duodenal portion of the intestine, beyond the pyloric valve of the long sacculated stomach, is furnished with numerous transverse folds confined also to its inner membrane. The colon enlarges into a small round sac before it reaches the anus. The number of the gas-

tric cœca varies in different species, the long posterior pair are the most constant. These sucking annelides live chiefly on the smaller aquatic animals which swarm around them in the stagnant waters they frequent. I have taken the entire legs and other parts of the common *triton cristatus* from the stomach of the *hirudo sanguisuga* so abundant in our fresh water pools. The intestinal canal is sacculated nearly through the whole extent in the *pontobdella;* but the numerous cells are here more short and round than in the leech where they generally taper to a point. The small mouth of the *halithea aculeata*, furnished with two conical tentacula or antennæ, opens into a short membranous œsophagus. which terminates in a large muscular stomach with thick firm parietes and a strong coriaceous lining. The entrance of this muscular cavity is furnished with four sharp, triangular, converging, horny teeth analogous to those of the gastric toothed cavity of insects and crustacea; and this sac is also analogous to the muscular stomach of the *arenicola*, *lumbricus*, and many other annelides, and to that of the *ascaris* and other nematoid entozoa. From this muscular gizzard, the intestine passes, thin, membranous and wide, through the middle of the trunk nearly in a straight course to the posterior terminal orifice, giving off from the dorsal aspect of its sides, at regular and short distances, long narrow cœca which send out numerous branches and terminate in elongated sacs. These two rows of elongated ramified cœca, coming off near to each other from the dorsal side of the intestine by long narrow ducts, and generally filled at their vesicular terminations with a soft turbid brownish-coloured matter, like that found in the cœca of an asterias, present a more extended, divided, and isolated condition, of the short cœca of the leech and the simpler biliary follicles of inferior annelides. In the *halithea*, which appears to subsist on a mixed kind of food, like the *pectinaria*, form the sand and fragments of shells commonly found in its intestine, the duodenal portion of the canal generally forms a slight reduplication, as in that animal, by folding backwards upon itself; but in the long articulated myriapodous forms of the *terebellæ*, *amphitrites*, and *nereides* the alimentary canal presents a more narrow and elongated character, and assumes a zig-zag or tortuous course in its distended state, and es-

pecially in the contracted state of the trunk. In the *nereides* there is generally an exsertile broad proboscis (Fig. 14. 1. *a.*) at the anterior end of the head, numerous lateral jaws which are remarkable for their frequent unsymmetrical number and development on the two sides of the mouth, a distinct gastric cavity furnished with longitudinal internal folds and with numerous sharp horny teeth, and an elongated intestine furnished throughout the greater part of its extent with lateral cœca, or biliary follicles, as in most of the higher annelides.

The digestive organs of the entomoid classes, like most of their other organic systems, are characterized by a more elevated grade of the same plan of development followed throughout the helminthoid articulata; and by the higher condition of their organs of sense and locomotion, they are better enabled to select their food, and to overcome more highly organized prey.

X. *Myriapoda.* In the long, equally developed, vermiform bodies of the myriapods, we still find an imperfect condition of the masticating organs, and the most simple helminthoid form of the alimentary canal, which accord with the characters of inferiority marked in their other organs, and with the cruel and carnivorous propensities these animals display in the living state. The masticating organs of the scolopendræ (Fig. 15), consist of a small pair of mandibles and a similar pair of maxillæ, which are followed by two pairs of larger jointed organs formed by the metamorphosis of the two first pairs of feet into masticatory jaws. The mouth is furnished with an upper and lower lip, and with long, simple, salivary follicles, like those of insects, enlarged at their closed extremities. The alimentary canal, like that of most of the higher annelides, passes through the whole longitudinal axis of the body, with thin membranous parietes, with little appearance of gastric enlargements, and without convolutions. The contracted œsophagus opens into a wider lengthened gastric cavity with thin parietes, and this elongated membranous stomach is succeeded, as in serpents, by a narrow small intestine which terminates in a perceptibly wider colon: so that the alimentary canal here presents affinities both to that of the higher forms of worms, and to that of the vermiform ophidian rep-

tiles. There appear to be three pairs of salivary glands of unequal lengths, extending along the sides of the œsophagus, in the scolopendra gigantea, besides two poison-glands placed along the lower maxillæ, which send their secretions to the two strong piercing grooved articulated hooks situated at the base of the jaws. From the elongated form of the stomach in the scolopendræ, the two wide extended biliary follicles have a low entrance into the alimentary canal, as in most insects. The stomach has the same broad elongated form in the *iulus*, where it is followed by a short small intestine, and a more wide and lengthened colon marked internally with transverse folds, and the biliary tubular follicles enter the lower end of the stomach. The single gastric cavity of the *lithobius* also receives, at its valvular pyloric extremity, the terminations of the two biliary tubes which extend forwards in a tortuous manner towards the head, and are supported by a small ligament at their closed anterior end. So that the two long terminal cœca of the stomach of the leech have now assumed the form of lengthened tortuous biliary vessels, as in the highest winged insects, and they here open into the lower end of the chylific stomach, as in most of the animals of that class.

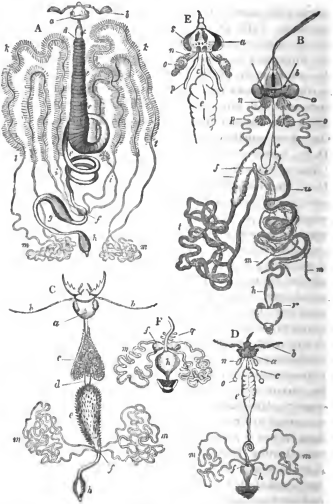
XI. *Insecta.* The digestive organs have arrived at a high degree of development in insects, and already present, in an embryo-state, almost all the assistant chylopoietic organs of the highest animals, as the liver, the salivary glands, the pancreas, and many other parts important in the process of assimilation. They vary much, however, in their form and extent of development according to the consistence and the nutritious quality of the food, the peculiar living habits of the species, and the condition of the animals with regard to their metamorphosis. The mandibulate forms of the masticating organs are best adapted for comminuting hard substances, and the tubular form or proboscis for sucking food in a soft or fluid state, but even suctorial insects require some form of these hard parts to pierce the surface from which they are to obtain their liquid food. The mouth of insects is furnished with an upper and lower lip (*labrum* and *labium*), a pair of strong proximate *mandibles* and a pair of exterior *maxillæ* which move transversely. The labium and the maxillæ support each a pair of *palpi*; the dense pos-

terior part of this lower lip forms the *mentum*, and its soft anterior portion supports the fleshy prominent *tongue*. The masticating organs present infinite varieties of form according to the difference of food in insects, as in other classes of animals, but the same constituent parts of the mouth can be recognized in all the different forms of mandibular and haustellar apparatus. The same buccal organs form broad, short, and strong cutting instruments, which move transversely, in those insects which subsist on hard food, and a long, slender, tubular apparatus, capable of extension and retraction, in those which suck fluid or soft substances. These parts often change from the one form to the other in the same insect, while it changes its kind of food in the progress of its metamorphosis; and where the food is the same in the larva and imago, the masticating organs preserve the same form in these two conditions of the insect. The food reduced by the mandibles and maxilla and mixed with the secretion of one or more pairs of salivary glands, is transmitted by a pharynx of variable length, to the œsophagus and alimentary canal. The œsophagus commences by a narrow canal which generally forms an enlargement of *crop* at its lower part, for receiving and collecting the food when first swallowed; this enlargement of the œsophagus is often covered with minute short glandular follicles which open into its interior. Below the crop is a small but strong muscular *gizzard*, with thick parietes, and provided internally with numerous longitudinal rows of hard sharp conical horny teeth. This muscular triturating stomach is most developed where the hardness of the food most requires its aid, as in most of the orthopterous and coleopterous insects; but where the food is liquid, as in most of the sucking hemiptera, the gizzard is scarcely perceptible. The largest, the most constant, and the most important gastric cavity in insects, is the long, wide and highly glandular *chylific stomach* which extends generally from the gizzard to the insertion of the hepatic ducts. The chylific stomach is, for the most part, amply furnished with considerable glandular follicles, which are developed from its whole parietes, and open by separate orifices into its interior. This cavity is frequently of great length, and partially divided by numerous transverse constrictions, it is then most wide and glandular at its anterior

or proximal part, becoming narrower like the intestine at its lower portion. The intestine, from the termination of the chylific stomach to the anus, is most variable in its length and capacity, and in the number and extent of its dilatations. Like the masticating organs, the gastric cavities and the whole alimentary canal have their forms regulated and impressed by the kind of food which they are destined to assimilate, or the quantity they are adapted to consume. In the voracious and inactive condition of the developing larva, the stomach is often found of enormous capacity compared with the diminutive size to which it is reduced in the more parsimonious and active state of the mature winged imago.

The alimentary canal of insects presents a distinct internal mucous lining, an external peritoneal coat, and muscular fibres, both transverse and longitudinal can be easily perceived in its parietes. The interior of the mucous coat presents a smooth surface, as in most of the lower invertebrata, having neither plicæ, nor valvulæ, nor villi, to increase its extent, and exterior to this there is commonly a loose cellular or follicular enveloping tissue. The exterior peritoneal coat forms a distinct thin mesentery, which is covered with the minute ramifications of tracheæ, and which connects the convolutions of the intestine with the interior of the abdominal segments. The ramifications of these white opaque air-vessels on the mesentery are seen in the common blue fly, and in most of the larger insects, without the aid of a lens, and appear like the branches of blood-vessels. The peristaltic motion of the intestine is obvious on opening the abdomen of the living insect; and in the short trunks of many of these animals, the intestine measures several times the length of the whole body. In insects, as in other classes of animals, the simplest forms of the alimentary canal, and of all the glandular organs connected with digestion, are those belonging to carnivorous species, from the already highly organized condition of their food requiring the least delay and the least change for its assimilation. In the *cicindela campestris* (Fig. 118. *c.*) which preys on other insects, the digestive canal passes nearly straight through the body. The œsophagus, commencing narrow as usual from the posterior opening of the head (C *a.*) dilates below into a wide

FIG. 118.



crop (C. *c.*) presenting several longitudinal rows of very minute follicles. The crop is succeeded by a short muscular gizzard (C. *d.*) and this by a capacious chylific stomach (C. *e.*) covered with numerous glandular follicles, and tapering downwards to its pyloric extremity (C. *f.*) where it is perforated on each side by two simple convoluted hepatic ves-

sels (C. *m.*) From the chylific stomach the intestine continues downwards very narrow, and nearly straight, to a short dilated colon (C. *h.*) which contracts before it terminates in the cloaca. In the common blood-sucking bug, *cimex lectularius* (118, D.) the whole digestive apparatus is more simple in its structure though more extended longitudinally, the alimentary canal being about three times the length of the short body of this insect. The mouth, armed with piercing and sucking organs, receives the secretions of two pairs of small salivary glands (D. *n. o.*) in form of simple follicles terminated by minute vesicles at their closed ends. The short capillary œsophagus forms a small conical crop (D. *c.*) before entering the lengthened cavity of the chylific stomach (D. *e. f.*) which is most dilated at its upper part (D. *e.*) but is susceptible of considerable distension throughout its whole course when filled with blood. The lower intestiniform portion of the chylific stomach, though here represented for greater distinctness as drawn out nearly to a straight course, is more convoluted in the short abdomen of the living bug, and receives on each side at its narrow pyloric termination (D. *f.*) the two orifices of short and simple hepatic vessels (D. *m.*) The remaining short and wide intestine (D. *h.*) generally distended with a thick reddish-brown coloured paste, the residue of digested blood, receives obliquely the pyloric end of the stomach (D. *f.*) above and contracts below into a narrow rectum before it terminates. Although the biliary vessels (D. *m.*) here, as in most insects, terminate in the stomach by separate orifices and without cystic enlargements, distinct reservoirs for receiving and collecting the bile are often developed at the insertion of these tubes. In the *pyrrhocoris aptera* (Fig. 118. F.) which feeds on the juices of the ripe fruits of malvacious plants, and the intestinal canal of which, though more lengthened and capacious, very much resembles in its whole structure that of the *cimex*, the chylopoietic glands are much more developed. There are three pairs of elongated salivary glands opening into the mouth, and on the lower pyloric extremity of the chylific stomach several minute simple pancreatic follicles (F. *q.*) are observed to open into its interior. The biliary vessels (F. *m.*) are not only lengthened and wide, but have thick glandular parietes, and they terminate on

each side in a single vesicular enlargement or gall-bladder (F. *f.*) before entering the stomach, which is here succeeded, as in the former insect, only by a short and capacious colon (F. *h.*) and narrow tapering rectum. In the *geocorises* all the lateral hepatic vessels terminate in a single median gall-bladder. In the mandibulate herbivorous insects, which subsist on coarser vegetable food, as the common coleopterous cockchaffer, *melolontha vulgaris* (Fig. 118. A.) which feeds on the leaves and shoots of our garden plants, the whole digestive apparatus is long, complicated, and capacious. The œsophagus passes out narrow from the head (A. *a.*) and dilates below into a short conical crop (A. *c*), which is succeeded by a very minute gizzard (A. *d.*) and a long convoluted chylific stomach (A. *d. e. e. f.*). The anterior portion of this lengthened glandular stomach is wide and sacculated by numerous transverse strictures, and terminates insensibly in a narrow convoluted pyloric part, which dilates into a small round vesicle at the lower end, where it receives the openings of the hepatic vessels (A. *f.*). The two hepatic vessels (A. *i. l. m.*) on each side are here, in accordance with the coarse nature of the vegetable food, very long, wide, and convoluted, and have their secreting surface greatly extended by the development of innumerable small lateral follicles (A. *i. k. l.*) which give them a pinnated form throughout the greater part of their course; thus presenting the most complicated condition of the liver met with in insects. The lower portion of the intestinal canal has also its capacity increased by distinct dilatations on the parts analogous to the colon (A. *g.*) and the rectum (A. *m.*) In the powerful, aquatic, insectivorous *naucoris aptera* (Fig. 118. E.) the whole form of the digestive organs closely resembles that of the cimex, but there is a short, narrow, small intestine between the chylific stomach (E. *e.*) and the colon, the pyloric end of the stomach dilates, as in many insects, into a small oval sac where it receives the hepatic vessels, the cardiac part of the stomach is wide and partially sacculated, and the crop (E. *c.*) forms an almost imperceptible dilatation at the lower end of a small elongated œsophagus. The posterior pair of salivary glands (E. *p.*) form wide cylindrical tubes which terminate by short narrow ducts in the mouth, and the two anterior shorter pairs (E. *o. n.*) divide at their closed extremities

into clusters of small follicles, already forming lobules, like the lobules of the tubuli biliferi in crustacea. There are three pairs of salivary glands, lengthened and complicated, in the *scutellera nigrolineata* which feeds on the young seeds of growing corn. The biliary tubes of this insect are very small, and they terminate in a single median vesicular enlargement, forming a minute gall-bladder. The chylific stomach, with its several convolutions and enlargements, composes, as in most insects, the greatest part of the alimentary canal. In the herbivorous *coreus marginatus*, which feeds on the juices of several plants, the digestive canal is more lengthened, but similar in structure. There are four pairs of large elongated salivary glands; two pairs of short simple biliary follicles pour their secretion into a single gall-bladder, and a pair of long sacculated pancreatic follicles terminate separately in the stomach above the entrance of the short cystic duct. This simple form of the pancreas is seen also in the *leptis, bombylius, chrysotoxum*, and many other insects. In the *cicada orni* (Fig. 118. B.) which appears to feed on the juices of the pine, and not of the ash tree, the long narrow tubular stomach (B. *t*), after forming numerous convolutions, returns to terminate in itself, like the intestine of a vorticella or the tubuli of many glands. In this, as in many other insects, there are two distinct forms of salivary glands which unite together to enter the mouth by a single duct on each side. One of these glands is a simple convoluted follicle (Fig. 118. B. *p*.) like the biliary and urinary tubuli, and the other gland on each side of the œsophagus forms a posterior (B. *o*.) and an anterior (B. *n*.) lobule, composed of small short follicles, before terminating in the common duct. The long capillary œsophagus dilates into a small crop (B. *c*.) before entering the cœcal cavity with which the chylific stomach (B. *e. t*.) commences, and from which the intestinal canal (B. *u*.) originates. The stomach (B. *e. f, t*.) in place of forming a continuous canal, as usual, from the œsophagus to the intestine, here turns off suddenly from the direct course of the alimentary canal, and, after forming numerous convolutions as a small tube (B. *t*.), it returns, to terminate in its proximal extremity (B. *f*.), thus forming a circular elongated tubular cœcum. At the commencement of this long circular cœcum, the stomach receives the termitnaions of four isolated monili-

form biliary vessels (B. *m. m. f.*). The small intestine (B. *u.*) originates from a cœcal cavity below the crop, and forms a narrow convoluted tube, which dilates into a small oval colon (B. *h.*) near the anus. This tubular anastomosing form of the stomach, with four similar sacculated biliary vessels entering its commencement, is seen in the *aphrophora salicina* and other insects of this family. In the *dorthesia characias*, the biliary vessels enter the narrow middle portion of a similar anastomosing convoluted gastric tube, and the stomach describes the same circular course in the *psylla ficus* where the biliary vessels are reduced, as in many other insects, to four short isolated follicles.

The salivary glands are nearly as general in the class of insects, as the biliary vessels, and they are often accompanied in predaceous insects, as in the *nepa*, with distinct poison-glands, which present the same simple follicular structure. Although the biliary vessels are most frequently four or six in number, and terminate generally in the phyloric extremity of the stomach, they often exceed a hundred, and terminate around two or more distinct parts of the lengthened gastric cavity. Where these primitive *tubuli biliferi* are very numerous, as in many orthopterous, neuropterous and hymenopterous insects, they are generally small, short, and separate at their distal extremity; where they are more lengthened and complicated they often anastomose at their free ends, as in the glands of higher animals. In most of the coleopterous insects with two sets of biliary vessels, whether simple or ramified, the ends of the anterior set anastomose with the posterior as in separate lobules. By the low and oblique insertion of the small intestine into the wider inferior portion, a distinct and often capacious cœcum-coli, analogous to that of vertebrated animals, is formed in many insects, as in *pelogonus marginatus*, *ranutra linearis*, *nepa cinerea*, and other species. The lower part of the intestine, also, frequently receives one or more urinary follicles, or *tubuli uriniferi*, which are found to secrete urea as in higher animals, and on which a small vesicle or urinary bladder is sometimes distinctly formed as in *ditiscus marginalis* and several other coleopterous insects. The alimentary canal of insects terminates in the cloaca along with the genital organs, as in oviparous vertebrata.

XII. *Arachnida.* The carnivorous character of the arachnida is indicated by the shortness and straightness of their alimentary canal, and by its small capacity, as well as by the poison-instruments with which they are often furnished, and by the imperfect development of their chylopoietic glands. They prey chiefly upon living insects, which their cunning instincts, and their offensive weapons enable them to ensnare and to overcome, and many parasitic species suck the living fluids from the surface of higher animals. The mouth of the arachnida, like that of insects, is furnished with a pair of strong articulated mandibles, which are here often perforated near the point for the transmission of a poison-duct, as seen in the spiders. The mouth is likewise furnished with a small pair of palpigerous maxillæ, a labium or inferior lip, and a lingua. The pharynx of the *spiders* leads to a short œsophagus, on which there are two pairs of small proventricular sacs, opening together into the same part of the canal, and which sometimes have the form of elongated follicles. The œsophagus continues narrow from this multiple crop, through the cephalo-thorax to the large abdominal cavity, which is chiefly filled with the biliary lobules and with the genital organs. The intestine here forms a small round stomach, and continues straight to the anus at the posterior end of the trunk, exhibiting a small dilatation or colon before it terminates. The palpi in the male spiders end in a wide oval bulb, containing the sexual organ, and in the female the terminal joint of the palpi is slender and elongated. In the parasitic *acari* the palpi are simple pediform extensions of the maxillæ, as in the spiders, and do not terminate in prehensile pincers, like the large palpi of the scorpions. There are several distinct follicular salivary glands in the *trombidium* and other genera, which pour their secretion into the mouth, like the two salivary glands of the scorpions. The maxillæ and tongue sometimes form a lengthened piercing and sucking proboscis, as in sucking insects. In the simpler tracheated species, the mouth appears sometimes to open by distinct orifices on both sides of the head, and their small stomach is furnished with numerous biliary follicles. The anal portion of the intestine in the spiders receives the secretion of several urinary follicles, which terminate in a small sac, or bladder, before opening

into the canal, as in many insects. The strong short mandibles and the large palpi of the scorpions terminate in prehensile organs, like the pincers of a crab, and embrace a capacious buccal cavity like the stomach of a crustaceous animal. From this wide oral sac, which is surrounded above by the ganglionic cerebral ring, the alimentary canal passes, narrow, tubular, and equal, through the abdomen and the tail, to the beginning of the last caudal segment, where it opens on the lower surface. In its course from the narrow œsophageal part, which passes through the nervous collar to its anal termination, the intestine of the scorpions forms neither crop, gizzard, nor gastric enlargement; but the portion contained in the abdomen, like a tubular stomach, is surrounded with the numerous lobes of the liver, which communicates with its interior by five pairs of short wide ducts, opening at regular distances along its sides. These five pairs of hepatic lobules are more isolated conditions of the ramified intestinal cœca of the *halithea* and other annelides, and at the lower part of this elongated stomach originate also four distinct ramified vessels, like some of the branched biliary vessels of insects, but which here communicate with the two anterior compartments of the heart, and with other parts of the vascular system, as if they conveyed nutriment to the blood. Thus, while the masticating organs of the arachnida approach these carniverous animals more nearly to insects, their straight and narrow alimentary canal, and the compact lobulated condition of their liver, connect them with the crustacea.

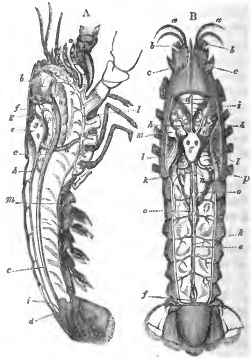
XIII. *Crustacea.* Like the spiders and scorpions of the land, the crustaceous inhabitants of the waters are cunning, cruel and carnivorous animals: with means of rapid locomotion and numerous acute organs of sense, and with a solid exterior protection and strong organs of prehension and mastication, they are well fitted for preying on all kinds of animals in the rich element they inhabit. They subsist on living or dead animal food both higher and lower than themselves in organization; most of them are in constant warfare with each other, and many, from being free, become fixed and parasitic in their adult state. The mouth in the higher crustacea is generally furnished with a pair of strong palpigerous mandibles, and five or more pairs of jointed extended maxillæ, which move transversely, and support likewise articu-

lated palpi; the three inferior or outer pairs of maxillæ are the largest and the most convertible in their forms, and support branchiæ at their base like the ambulatory feet. The entrance of the mouth presents an upper lip, a bifid tongue, and sometimes a small under lip, formed by a pair of maxillæ. The maxillæ are often reduced to one or two pairs, or are wanting, in the lower crustacea. One or more of the anterior pairs of ambulatory feet generally terminate in strong pincers like the palpi of the scorpions. The wide buccal cavity of the decapods, surrounded with complicated organs of sense and of mastication, opens by a very short and narrow œsophagus into a capacious stomach, provided internally with several pairs of solid calcareous teeth, and occupying the anterior part of the cephalo thorax. As their watery element almost bathes this gastric cavity, they require no salivary glands to soften their moist food. The gastric teeth, colored and shed like the exterior shell, are symmetrically disposed near the pylorus, and are supported by thin elastic calcareous laminæ, to which powerful muscles are attached, and which cause the teeth to meet with precision in grinding the contents of the stomach. In many of the parasitic species attached to the surface of fishes, the mouth forms an extended syphon composed of the prolonged lips, and embracing the long, sharp, piercing mandibles, and in the *limuli* all the masticating organs around the mouth have the form of ambulatory feet, terminating in pincers.

As in most other carnivorous articulata, the alimentary canal of the crustacea passes, without convolutions, through the longitudinal axis of the body, and opens by distinct apertures at its two extremities. The mucous coat forms often rugæ or folds in the wide œsophagus and stomach, but passes smooth through the rest of the canal; the muscular layer is strongest at the orifices of the stomach, and the peritoneal covering, as in insects, forms no mesentery in the abdomen. The pyloric extremity of the stomach, near which the gastric teeth are disposed, receives on each side a short and wide duct from the large and lobated liver which envelopes this part of the cavity and the beginning of the intestine. The gastric teeth are common to the crustacea with insects and other articulata, and many molluscous animals. The hepatic duct on each side of the narrow

muscular pyloric extremity of the stomach divides into numerous smaller branches; these terminate in groups of minute follicles, which compose the lobes and lobules of the liver. The hepatic lobes in the larger decapods envelop the œsophagus and sides of the stomach, extend backwards above or between the branchial cavities, and beneath the heart and genital organs, and fill the greater portion of the abdominal cavity, as seen in the annexed figures of the male lobster, *astacus marinus* (Fig. 119. A. B.) by W. Bell, where A represents a vertical longitudinal section of the trunk viewed laterally, and B a dorsal view of the principal thoracic and abdominal viscera. The maxillæ (119. A. *a*.) and mandibles, with their palpi, are placed on the inferior aspect of the head,

FIG. 119.



between the anterior large ambulatory limbs and the two pairs of antennæ (119. B. *a*. *b*.). The two pedunculated

compound eyes (B. *c. c.*) are lodged in orbital cavities above the broad peduncles of the large exterior antennæ (B. *b.*), and are protected by a spiny prominent median rostrum. The short vertical œsophagus opens into a capacious muscular stomach (A. *b.* B. *d.*) in which the teeth are disposed in pairs near the contracted pyloric extremity, and which is surrounded by the numerous lobes of the liver (A. B. *n. n. n.*). The intestine (A. *c.* B. *e.*) receives at its commencement the two hepatic ducts, and passes beneath the heart, (A. *e.* B. *g.*) the testes (B. *o. o.*), and the posterior aorta (A. *h.* B. *k.*), following nearly a straight course to the anus (A. *d.*) which is situate below the last segment of the trunk. The abdominal cavity, containing these viscera is separated from the thoracic containing the branchiæ (B. *l. l.*) by a strong tendinous diaphragm (B. *m.*). The colic portion (B. *f.*) embraced by the bifurcation (A. *i.*) of the posterior aorta (B. *k.*) is more wide and dilatable than the rest of the canal, like the colon of insects, and it is provided below with its muscular sphincter, and sometimes with a valvula coli at its commencement. Besides the biliary tubuli which compose the large symmetrical lobes of the liver, and which are sometimes reduced to a few pairs of simple follicles in the lower crustacea, two or three pancreatic tubuli, lengthened and isolated, are occasionally observed to enter the pyloric portion of the intestine in the higher decapods, and the soft rudiments of salivary glands are perceived at the sides of the œsophagus in the same animals. The stomach and alimentary canal (119. A. *b. c.* B. *d. e.*) occupy the dorsal portion of the trunk in the crustacea, and not the ventral part, as in the vertebrata, which corresponds with the general inverted condition of the other organs of the body in the articulated classes. Although the stomach is thus large and powerful in the higher mandibulated predaceous forms of this class, there is often no perceptible gastric enlargement in the short straight intestine of the lower sucking parasitic species. Thus the alimentary canal and the chylopoietic glands are comparatively limited in their development in all the entomoid, as in the helminthoid forms of articulata, which corresponds with the general carnivorous character of these animals, their inferior position in the scale, and the highly organized con-

dition of the animal matter on which they commonly subsist.

FOURTH SECTION.

Digestive Organs of the Cyclo-gangliated or Molluscous Classes.

The low development of all the organs of sense and locomotion throughout the molluscous classes, compared with those of the articulata, renders them less able to select and overcome the higher forms of animals as prey, and requires their digestive apparatus to be adapted for a more coarse and varied kind of food. The slow moving or fixed animals of this division, subsisting on organic matter in a lower condition of development, and consequently more remote from their own nature, possess a more extended and complicated alimentary canal, and a higher development of biliary, salivary, pancreatic and other glands, to assist in the complex process of assimilation. The digestive canal of the mollusca almost never passes straight through the body, nor is the posterior orifice terminal, as it is in most of the articulata. The gastric cavities are more distinct, more numerous, and capacious; the intestine is more lengthened and convoluted, and the chylopoietic glands are not only larger, and developed on a higher plan, but are more constant throughout the cyclo-gangliated classes, than in the long extended trunks of the active and carnivorous worms and insects. The softness or subdivided nature of their food, and the magnitude of their hepatic, salivary, and other glands, enable the molluscous animals to dispense with the numerous solid instruments of mastication and prehension disposed around the mouth in the articulated tribes, and their whole economy being thus adapted for the absorption and solution of the softer and inferior kinds of organized matter, teeth or other dense parts are more rare in their digestive sacs, than in the entomoid and even the helminthoid classes.

XIV. *Tunicata.* The tunicated animals, the lowest and simplest of the molluscous classes, subsisting on the minute organic materials suspended in the waters of the sea, and

having their buccal aperture situate at the bottom of a deep respiratory sac, through which the aqueous currents are conveyed, exhibit no prehensile nor masticating apparatus nor distinct organs of sense connected with the mouth. Delicate tentacular filaments (Fig. 88. *c.*), analogous to the palleal tentacula so common and numerous in the conchifera, are generally disposed around the interior of the ciliated branchial orifice (88. *a.*), and also of the anal aperture (88. *b*) or of the anus (88. *i*), to guard these passages from the intrusion of noxious bodies; both these orifices serve sometimes for the entrance and sometimes for the exit of the currents which aerate the branchiæ and bring food to the mouth. The oral tentacula are wanting in the *pyrosoma;* they are simple filaments in the *phallusia*, and are ramified in some of the *cynthiæ*. They are generally more simple around the vent and around the anus than at the respiratory orifice, and in some species small red ocular points are seen around both the respiratory orifice and the vent. There are six of these red ocular points around the vent, and eight around the branchial orifice in the common soft transparent green-coloured *ascidia intestinalis* of our coasts, and they resemble the rudimentary eyes met with in many of the simpler forms of radiated and helminthoid animals. The inner surface, and marginal tentacula of the respiratory aperture, are ciliated to produce the currents, as in conchifera. The mouth, or entrance of the œsophagus, generally forms an oblique transverse aperture, with loose sensitive lips, at the bottom of the respiratory sac, as seen in the *cynthia* (88. *g.*), so that the food arrives at that aperture directly from the respiratory orifice, (88. *a.*), before the currents have passed out through the minute ciliated perforations of the branchial cavity. The short and wide œsophagus leads to a distinct gastric cavity (88. *h.*) sometimes plicated longitudinally, and perforated at its pyloric extremity with the orifices of the wide ducts from the biliary follicles. No teeth, nor jaws, nor salivary glands are perceptible at the entrance of this very simple alimentary canal, but the stomach forms a distinct enlargement, even in the lowest species, and the liver is nearly as constantly observed under some follicular form, opening into its cavity as in the stomach of conchifera and almost all the higher mollusca. The pyloric portion of this simple membranous

stomach, and also a part of the intestine, are generally surrounded with the soft granular substance of the liver, which presents an appearance of minute lobules from the grouping of its component follicles. The intestine, on leaving the stomach, forms a sigmoid curvature in the abdominal cavity on the back part of the respiratory sac, ascending towards the exterior vent near which it generally terminates with a fringed margin (88. *i.*). The intestine, covered with peritoneum, highly vascular, without mesentery, and without cœcal or other enlargements, occupies a cavity not traversed by the respiratory currents, and has on its convex posterior part, the heart and aorta, and on its upper or anterior part, the ovaria (88. *k.*) and oviducts (88. *m.*), as in the bivalved mollusca. The respiratory currents, after traversing the ciliated perforations of the branchiæ, pass out by a distinct canal, over the anal aperture and the generative orifices, to the exterior vent, so that the ex-currents, aided by the contractions of the general muscular tunic, assist in expelling the products of generation and the residue of digestion, as in the conchifera. The respiratory orifice, for the entrance of the currents and of the food, is generally larger than the vent by which they are expelled, and the two apertures of the alimentary canal, the mouth and anus, are variously approximated to the exterior orifices of the enveloping tunic in the different species of this class. The anal aperture of the intestine, which projects free into the expiratory canal, is generally lobed or fimbriated or valvular as in many of the higher mollusca. In some of the compound tunicata the liver is not distinguishable; in the pyrosoma it is divided longitudinally into several lobes which communicate with the intestine by distinct ducts; in some cynthiæ it forms a glandular layer of minute follicles over a part of the intestine, or of the stomach, as in the *cynthia canopus*, and in others, as the *cynthia momus*, the liver presents a more definite character and form, as in higher classes. The convoluted alimentary canal is commonly filled with a dark-coloured flocculent mucous matter, like that found in the intestine of most conchifera, and although the nature of the food is not distinguishable in this soft digested matter, small entomostracous crustacea are often found within the respiratory sac, and probably form a principal part of their food. This dark matter filling the intestine renders

visible the course of the convoluted digestive canal through the abdominal cavity, where it is generally found ascending on the right side of the respiratory or thoracic cavity in the higher isolated forms of tunicata, and is contained beneath that cavity in many of the lower compound forms. As the short component follicles of the liver open freely into the alimentary canal, their contents are often tinged with the colour of the food, and thus give rise to a diversity of colour in the liver of these animals. In the *cynthia dione*, the hepatic follicles are long and isolated, and envelop the stomach, as the pancreatic follicles or *cæca pylorica* envelop the pylorus in most osseous fishes, and in this cynthia, as in some others, the turns of the intestine are in contact with each other throughout their course, and the buccal and anal orifices are nearly approximated. In the *botryllus* and other compound tunicata, each component animal has its own distinct organs for nutrition and generation, constructed on the same plan as in the isolated species, the respiratory orifices of the botryllus open separately on the surface, around a large central aperture which gives exit to all the ex-currents of the separate vents. The prominent papillæ which cover the exterior surface of the *pyrosoma* (Fig. 119. 2 *c*.) have each a respiratory orifice near their apex, and the currents pass through the body of each component animal to the anal apertures situate in the interior of the general tube formed by the aggregation of all the individuals. Near the bottom of each reticulated ciliated respiratory sac is the small round buccal orifice leading by a short narrow œsophagus to a simple globular stomach; the intestine, furnished with a distinct liver, forms a single convolution, and terminates near the vent. On opening the general tube of the *pyrosoma* the numerous small vents of the respiratory sacs are observed, by which the currents pass into the tube and move it through the sea.

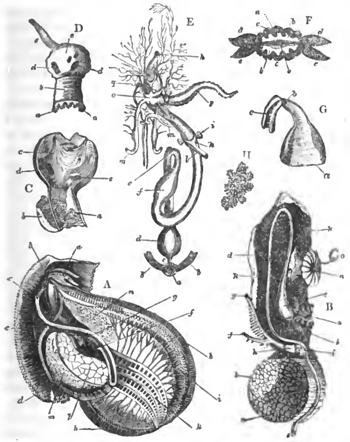
XV. *Conchifera*. The general plan of structure in the digestive apparatus of the inhabitants of bivalve shells is very similar to that of the tunicated mollusca, but they present a more complicated and higher condition of development in the several organs. The conchiferous animals are commonly fixed or slow in their movements, and,

without prehensile or masticating organs, they depend on the respiratory currents for their supply of food. The two respiratory apertures reach to a variable extent from the opening of the valves according to the habits of the species, and are generally provided with tentacular filaments, and sometimes with minute organs of vision, as in some of the tunicata. The buccal orifice of the alimentary canal is situate at the bottom of a large respiratory cavity, in which the branchial folds are suspended, and is provided with two pairs of long lateral lamelliform tentacula, which are extensions of the upper and lower lips. The mouth is unprovided with mandibles, or maxillæ, or any form of solid dental apparatus, and opens by a short and wide œsophagus into a capacious gastric cavity, perforated, as in the tunicata, with the numerous openings of the biliary ducts. The stomach is generally a soft membranous or muscular cavity, destitute of teeth, of an elongated form, and surrounded by the lobes of a large and conglomerate liver. On opening the stomach, several perforations are seen near its pyloric extremity, which lead by short wide ducts to the ramifications and follicles composing all the lobules of the liver, the liver consisting here, as in other molluscous classes, of an aggregate of minute follicles or cœca, the ducts of which unite into larger trunks and terminate in the pyloric portion of the stomach. The intestine is generally long and wide, corresponding to the simple and inferior nature of the food brought to these animals in small parts by the respiratory currents. On leaving the stomach, the intestine forms a few convolutions in the cavity of the abdomen, closely surrounded by the lobes of the liver, then proceeding along the convex dorsal part above the ovary and the thoracic cavity, it commonly perforates the cavity of the muscular ventricle, and terminates near the vent for the exit of the respiratory currents, as in the naked acephala.

The mouth in the common oyster *ostrea edudis* (Fig. 120. A. *b*.) is concealed, as usual, at the back part of the cavity of the mantle, near the hinge of the valves, and is furnished on each side with two long tapering fleshy tentacular folds (A. *a*.) which are striated like gills on their inner surface and smooth on their exterior. The buccal aperture leads almost

directly into an elongated capacious stomach, which is perforated by the wide ducts of a large liver (A. *n.*), and the alimentary canal, passing through the substance of the liver and in front of the auricle (A. *f.*) and ventricle A. *g.*) returns upon itself on the fore part of the large adductor muscle.

FIG. 120.



(A. *l. m.*). After returning to the stomach and forming a loop round that cavity, the intestine (A. *c. c.*) passes along the dorsal part of the body to the anus (A. *d.*) without perforating the cavity of the heart (A. *f. g.*) which is here enclosed with its pericardium in a groove on the fore part of the adductor muscle of the valves. The currents which bring

food to the mouth are produced, as in other conchifera, and in tunicata, by the vibratile cilia disposed on the branchial folds (A. *b.*) and on the surface of the mantle (A. *i.*) enveloping the respiratory cavity. The very long labial tentacula of the *pinna nobilis* (Fig. 120. E. *b.*) extend laterally from the lobed margin of the mouth (E. *a.*), and are striated like branchiæ on their inner surface. The short narrow œsophagus (E. *c.*) leads to an elongated stomach, wide at its cardiac portion (E. *d.*), and narrow and valvular at its pyloric end (E. *e.*), where it forms a small round cœcum. A distinct pyloric valve (120. G. *b.*) is formed by a circular fold of the mucous coat at the angular junction of the stomach (120. G. *a.*) with the small intestine (120. G. *c.*), as in most mollusca and fishes. On opening the cavity of the stomach, strong muscular bands (120. C. *c.*) are seen around its pyloric portion, and several large oblique apertures (120. C. *d. e.*) leading into the lobes of the liver are found near to the duodenum (120. C. *a.*). The curved duodenal portion presents a considerable enlargement (120. E. *f.*), and a similar dilatation is observed near the end of the colon (120. E. *g.*) as in many insects. The colon of the conchifera generally pierces the ventricle of the heart or the commencement of the two aortæ, and passes longitudinally through their cavity. The part of the intestine which traverses the heart, and the portion imbedded in the substance of the liver are commonly found to contain food when the rest of the canal is empty. The stomach of several of these animals is frequently observed filled with mucus, sand and mud, as if they merely strained the agitated waters of their turbid contents to obtain their food, as the echinoderma and annelides mostly obtain their nutriment by passing the sands of the bottom of the sea through their intestine. The liver presents diversities of conformation in this class as among the tunicata. In the *mactra* the bile enters the stomach by a single wide duct, as in the cephalopods, and the component cœca or biliary tubuli are large and distinct. From the simple condition of the liver in the conchifera, the numerous minute tubuli biliferi which compose its lobes are easily rendered perceptible by removing the peritoneal covering, and floating a small detached portion in water, as seen at (120. H.) In most conchifera the convolutions of the intestine are contained in an abdo-

minal cavity embraced by the expanded base of the muscular foot, which thus separates it from the respiratory or thoracic cavity, like a diaphragm. The convoluted part of the canal is generally either covered by the compacted lobes of the liver, or is disposed between that organ and the ovary. The terminal portion of the intestine or the colon, in the *solen strigilatus*, traverses not only the ventricle of the heart, as in other conchifera, but also a part both of the anterior and posterior aortæ which arise from the ventricle. In the *mya pictorum* the colon passes through the middle of the anterior aorta into the ventricle of the heart, but immediately escapes through the parietes of that cavity and follows along its exterior surface; it again penetrates the posterior portion of this elongated ventricle, and continues for a short distance through the cavity of the posterior aorta.

There is a firm cylindrical stiliform body, of crystalline transparency, enclosed in a cœcal prolongation or membranous sheath, which opens into the cavity of the stomach in many of the animals of this class. This stiliform gastric dart has a tricuspid free extremity, is of a cartilaginous consistence, and is composed of several concentric laminæ; it appears to be analogous to the cartilaginous styles common in the proboscis of the gasteropods, and to be connected with mastication; its sheath runs along the duodenal part of the intestine, and opens into the stomach. It was considered as a masticating organ by Meckel, and as an organ destined to close the biliary passages by Poli, who first described it; it is seen in the *cardium, mactra, donax, tellina, venus, arca, solen*, and its sheath has sometimes been mistaken for a second stomach. The rectal part of the intestine terminates near the vent, above the posterior adductor muscle in the dimyaria, and behind the single adductor muscle of the monomyaria, as seen in the *oyster* (120. A. *d.*), and in the *spondylus* (120. B. *e.*) The long, striated, ciliated, branchiform labial tentacula vary in their forms in different species, and their fimbriated or ramified varieties lead to the forms of the prolonged arms of the brachiopodous conchifera. In the *spondylus gaideropus* (120. B. D. F.) the mouth (B. *a.* F. *a.*) is bounded by lobed lips (F. *b. b.*) the lobes of which terminate in elegant red-coloured fimbriated tufts (F. *c. c.*) and the lips themselves are continued laterally into the usual upper (F. *d. d.*) and lower (F. *e. e.*) pair of labial tentacula

(B. *b.*). The narrow short œsophagus leads to an elongated stomach (B. *c.*) covered by the lobes of the dark green-coloured liver, and the intestine (B. *d. e.*) passing backwards between the lobes of the ovary (B. *k. k.*) and forming one convolution, returns to the upper part of the shell, or of the abdominal cavity, where it penetrates the ventricle (B. *i.*) of the heart (B. *h. i.*). Escaping from the cavity of the heart, the intestine ascends, as usual, over the great adductor muscle (B. *l. s. m.*) of the valves, and terminates by a simple anal opening (B. *e.*) near the respiratory vent. On opening the mouth (120. D. *a. a.*), the œsophagus (D. *b.*), and the stomach (D. *c.*), we perceive the limits of the lobed lips (D. *a.*) the muscular fibres and transverse rugæ of the œsophagus (D. *b.*), and the numerous apertures (D. *d. d.*) of the stomach, by which the bile is poured into that cavity to mix with the food before it is sent into the small intestine (D. *e.*) The intestine (B. *d. e.*) is not perceptibly perforated in its parietes in the part which is contained within the ventricle (B. *i.*) in this or other conchifera. The blood from the palleal (B. *f.*) and the branchial (B. *g.*) veins enters the two lateral portions of the auricle (B. *h.*), by which it is sent into the ventricle (B. *i.*), and from this it is distributed by an anterior and posterior aorta for the nourishment of all parts of the body. So that the digestive organs of the testaceous acephala exhibit a higher development than is presented by the naked species, chiefly in the large and often complicated buccal appendices, the gastric stiliform cartilage, the constant presence and great development of the liver and the length of the alimentary canal, and it differs from that of the tunicated species, by its passing through the muscular ventricle of the heart, by the greater number of its convolutions, and by the greater extent of its course, being enveloped in the mass of the liver.

XVI. *Gasteropoda.* The numerous and diversified class of gasteropods presents a more complicated and more varied digestive apparatus than the acephalous mollusca, which accords with the greater variety observed in their food and habits; for most of the terrestrial pulmonated species feed on the highly organized vegetables of the land, while the naked marine gasteropods, as the *doris*, *eolis*, *scyllæa* and *tritonia*, subsist on the lowest fuci of the sea, and most of the pro-

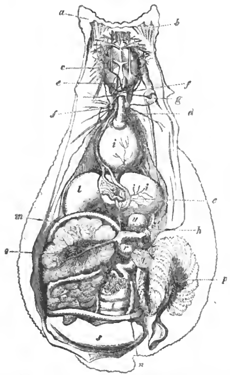
boscidian species are carnivorous and feed on living prey. The mouth of the gasteropods is placed at the anterior end of the body, is furnished above with one or more pairs of tentacula and generally with a pair of eyes, and contains often a pair of smooth horny lateral jaws, a fleshy tongue supporting numerous recurved horny spines, or a long muscular proboscis armed with numerous sharp recurved spines at its extremity. The pharynx is generally a capacious cavity furnished with distinct layers of circular and longitudinal muscular fibres, and stronger fleshy bands to advance and retract it. One or two pairs of salivary glands, considered by Meckel as pancreatic, extending along the sides of the œsophagus, send their ducts into the mouth at the base of the tongue. The œsophagus is longer than in the acephalous mollusca, and is especially lengthened in the carnivorous proboscidian gasteropods which mostly inhabit turbinated shells. There is sometimes, as in the *buccinum,* an enlargement or crop formed in the course of the œsophagus, as is common in insects and cephalopods. The stomach forms always a distinct cavity, often of great size, and is sometimes divided in the phytophagous gasteropods, as in the *aplysia,* into several compartments. The pyloric end of the stomach receives by several wide ducts the secretion of a large liver, and sometimes also that of one or more pancreatic follicles. The interior of the stomach is often provided with teeth, like the stomach of the crustacea and the gizzard of insects and sometimes with a pyloric valve. The liver is of great size in this as in other molluscous classes, its lobules are composed of more lengthened *tubuli biliferi* than in the conchifera, and generally envelop the intestinal canal as in these acephala. The gastric dart with its cœcal sheath is not developed in the gasteropods, and the intestine, destitute of mesentery, is more lengthened and more convoluted than in the conchiferous class, especially in those gasteropods which feed on vegetable substances. In the carnivorous species where the œsophagus is lengthened, the stomach is generally small and the intestine short and narrow. The intestine, supported only by vessels and cellular tissue, is sometimes enlarged at its anal portion to form a colon, but is without *cœcum* or *valvula coli;* and instead of terminating, as in the articulated classes,

at the posterior end of the trunk, it commonly opens, along with the genital organs, on the right side nearer the anterior extremity of the body. This lateral termination of the alimentary and genital organs in the gasteropods, and also the lateral position of their heart and respiratory organs, accord with the want of bilateral symmetry remarkable in the lower mollusca when contrasted with the articulated classes.

In the *doris* which feeds, like most of the naked gasteropods, on marine plants, the mouth is furnished with a pair of broad labial tentacula, as in the *haliotis*, and resembling those of bivalved mollusca, besides the ordinary vertical cephalic pair, and, though destitute of jaws, it is provided with a lengthened tongue extended through the pharynx. The cartilaginous surface of the tongue is covered with minute sharp recurved spines, as in most other phytophagous species destitute of jaws, and the short wide muscular proboscis and pharynx lead to a long, wide and tortuous œsophagus. Both follicular and conglomerate salivary glands pour their secretions into the mouth, and the capacious round membranous stomach is perforated at its pyloric portion with the numerous wide ducts of a large enveloping liver, and with the oblique opening of a large single pancreatic follicle which is wanting in some of the species. From the stomach the wide intestine passes around the left side of the liver to the posterior end of the abdomen where it perforates the auricle of the heart and opens on the dorsal aspect of the body in the space surrounded by the branchiæ. Close to the anus, in this branchial space, there is likewise the opening of an excrementitious gland imbedded, like the ink-gland of the octopus, in the substance of the liver; there is a small round sac developed on the duct of this renal organ, like a urinary bladder. The *aplysia faciata* (Fig. 121) feeds, like the *doris*, on coarse marine plants, and therefore presents a complicated condition of all the chylopoietic viscera. Anterior to the long conical cephalic tentacula are a pair of minute dark coloured eyes, and the broad labial tentacula (121. *a.*) are moved by strong muscular bands (121. *b.*) The lips are supported by two cartilaginous laminæ, and the tongue is covered with minute recurved teeth. The wide muscular cavity of the mouth (121. *c.*) receives the terminations of two lengthened follicular salivary tubes (121. *e. e.*), and lies over a large

infra-œsophageal ganglion which is connected by two nervous bands with the broad supra-œsophageal or cerebral ganglion (121. *f.*) The short narrow œsophagus (121. *d.*) passes through the double ganglionic ring (121 *f. f.*), and dilates into a large membranous crop or curved sac (121. *i. i.*) generally filled with pieces of fuci. This large crop or paunch occupies the right side of the abdomen and opens laterally into the smallest or middle stomach (121. *k.*) which is provided internally with numerous broad, flat, horny teeth of a rhomboidal form, which serve to compress the softened vegetable matter transmitted in small portions from the first stomach. The third cavity (121. *l.*) of this complex stomach is placed on the left side of the abdomen; it receives by several wide ducts placed in a valvular recess at its pyloric orifice, the secretions of a large lobed liver (121. *o.*) and of a long single pancreatic follicle; and its inner parietes are furnished with several sharp horny spines to subdivide the coarse food, or to pierce it for the ingress of the solvent gastric fluids. The intestine (121. *m.*) on escaping from the third stomach forms several convolutions round the lobed liver (121. *o.*), and after a lengthened course, without forming any further enlargement or internal valve, it opens on the right side (121. *n.*) near the posterior extremity of the body and immediately behind the heart (121. *q. r.*) and the large pectinated branchiæ (121. *p.*) As in

FIG. 121.



most of the higher mollusca, the organs of generation occupy the posterior part of the abdominal cavity, especially the ovary (121. *s.*) and the testicle (121. *t.*) with its convoluted epididymis, but the common canal of both these organs ascends on the right side to the penis (121. *g.*) near the head, and the urinary sac (121 *u.*) opens into the same common excretory passage.

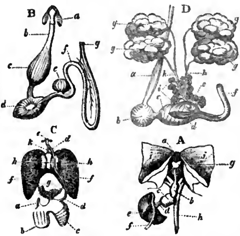
There are four gastric cavities in the *pleurobranchus* of Peron, and the capacious stomach of the *pleurobranchea* extends nearly the whole length of the body. Horny teeth are found in the stomach of the *tritonia*, *scyllœa*, and most other phytophagous gasteropods; in place of teeth the stomach of the *tethys* is lined with a firm coriaceous epithelium; and the sides of the muscular round stomach of the *bullæ* are provided with two dense rhomboidal horny plates, with their convex surfaces directed inwards towards each other to masticate the food. In the *patella* the tongue is longer than the whole body, and is covered over with regular transverse rows of sharp recurved spines for filing down the coarse marine plants on which it subsists. The œsophagus is wide and sacculated at its upper part, and passes narrow through the liver nearly to the posterior extremity of the body before entering the capacious transverse stomach which has an elongated form with its orifices terminal, and the intestine, long and convoluted through the mass of a large liver, terminates in a slightly dilated rectum which opens on the right side near the head. There are two horny maxillæ in the *tritonia* and *scyllœa*, besides the usual sharp spines on the surface of the tongue, and in the *limnœa* and *planorbis* there is a superior dentated maxilla besides the two ordinary lateral jaws. These maxillæ are articulated together; they are moved by powerful enveloping muscles, and they are lateral in their position like those of articulated animals. There is a superior dentated jaw in the *snails* for reducing their vegetable food; there are three gastric sacs in the *onchidium* which are plicated longitudinally within, and the biliary ducts here enter the œsophagus as well as the stomach. The rectum opens on the right side in the naked *limaces*, as in the testaceous *helices*, on the median line in the *testacella* as in the *doris*, and on the left side in the *planorbis* which has the apex of its suborbicular shell slightly

directed to that side, as in reverse shells where a similar transposition is seen in all the viscera. The higher carnivorous proboscidian gasteropods, armed with an operculated turbinated shell, and for the most part pectinibranchiate and with the sexes separate, have generally sharp teeth placed on a divided tongue at the end of the long muscular proboscis. These teeth, like maxillæ, are supported by two long stiliform cartilaginous pieces, like the gastric cartilaginous dart of conchifera, and are moved like jaws by powerful muscles, as seen in the *buccinum undatum* (Fig. 66. *a.*) Through the axis of this muscular tube passes the œsophagus, and between them run the long ducts of the salivary glands to the mouth at the free extremity. The œsophagus is therefore of great length in these predaceous animals, and is sometimes provided with a small crop on entering the abdominal cavity. The stomach is small, simple, and membranous, and the short intestine forms a wide colon in advancing along the right side of the body to terminate near the neck, on that side, under the mantle.

XVII. *Pteropoda.*—These small swimming mollusca appear to feed, like conchifera, on minute animals or organic particles suspended in the waters they inhabit, and their digestive apparatus is formed on a plan nearly as simple as that of the inhabitants of bivalved shells or of the lowest gasteropods. No teeth are perceptible in the triangular fleshy mouth of the *clio borealis*, but long follicular salivary glands open into the sides of the buccal cavity, as in the *pneumodermon*, and the œsophagus, after passing through the usual cerebral or ganglionic ring, dilates into a long wide membranous stomach surrounded by the lobes of a large liver and perforated by their ducts. From this lengthened stomach the short intestine, still destitute of mesentery, turns upwards in a slightly convoluted direction, on the left side, to terminate on the neck under the left gill, the mantle of the pteropods being closed above, and there being here no median open funnel for the excretions as in the cephalopods. The œsophagus is generally lengthened in the pteropods as in the gasteropods, while it is very short in the conchifera and tunicata. The stomach is perforated by the biliary ducts, and the intestine is enveloped in the hepatic lobes in the *pneumodermon*, as in the *clio*. In the stomach of the *cimbulia* there are dense

horny teeth, as in several of the gasteropods. The simple unarmed mouth of the *hyalea* (Fig. 122. A. *a.*) leads into a narrow lengthened œsophagus which passes under a broad cerebral ganglion (122 A. *g.*), and dilates in the abdominal cavity into a membranous crop (122. A. *b.*) which is slightly marked internally with longitudinal plicæ. This first cavity opens directly into a short cylindrical muscular gizzard (122. A. *c.*) likewise marked with longitudinal folds on its inner surface, and lying, like the crop, over the great retractor muscle (122. A. *h.*) by which the animal withdraws its head and fins (A. *i. i.*) into its shell. From the muscular gizzard the long narrow intestine (122. A. *d. e. f.*) makes a double turn round the lobes of a small liver, and continues nearly of uniform thickness to its termination on the right side of the neck under the right branchial fin. The mouth of the *pneumodermon* is furnished with two lateral retractile tentacular tufts composed of minute pedunculated suckers resembling those of a naked cephalopod, and two long and wide salivary follicles which dilate each into a small sac before they open into the muscular buccal cavity. The surface of the tongue is covered with small sharp recurved spines, and the capacious membranous stomach is perforated with numerous minute openings of the enveloping lobes of the liver as in many of the acephalous mollusca.

FIG. 122.



XVIII. *Cephalopoda.*—These animals being mostly free, naked, and predaceous, are provided with powerful organs of prehension and of mastication, and their short alimentary canal is furnished with highly developed salivary, biliary, and pancreatic glands. The mouth, surrounded by strong muscular feet, and bordered by minute labial tentacular

filaments, is covered with sensitive and retractile lips which move by distinct levator and sphincter muscles. The muscular bulb of the mouth contains, in the naked species, two strong, curved, sharp, horny mandibles, like those of many oviparous vertebrata; but in the *nautilus* (Fig. 122. B. *a.*) the jaws are calcified and possess broad and dentated margins. The lower mandible extends beyond and curves over the point of the upper, and both are hollow behind and expanded at their base, like the vaginiform horny mandibles of many vertebrata. The mandibles here move vertically as in all the higher classes, not transversely as in articulata. The short muscular tongue is covered with regular rows of sharp horny recurved spines as in many molluscous and vertebrated animals, attached to a cartilaginous base, and the back part of the mouth receives the secretions generally of an upper smaller pair and an inferior larger pair of salivary glands, the component tubuli of which have already assumed the conglomerate form and lobulated character of these organs in higher classes. The inferior or large pair of salivary glands are situate at the upper and back part of the liver, and their two ducts early unite to ascend to the mouth as one median canal.

The œsophagus of the cephalopods passes through the cranial cartilage, and continues for a short distance narrow and equal, behind the upper end of the elongated liver, then dilates into a crop, which sometimes forms a short circumscribed membranous cavity, and in others a simple elongated dilatation, as we see the forms of that organ to vary in the class of birds, and it is generally marked with longitudinal plicæ of its internal mucous coat (122. B. *b. c.*) Below this dilatable first cavity the œsophagus continues downwards narrow, and to the right side of the dorsal part of the cavity of the trunk, where it enters the second stomach or muscular gizzard. The crop forms a short circumscribed cavity, and is high in its position, in the *octopus*; it is lower and more elongated in the *nautilus* (122. B. *c.*) more narrow in the *loligopsis* (122. D. *a.*), and scarcely forms a perceptible dilatation in the *loligo* and the *sepiola* (122. C. *a.*) The muscular gizzard, situate on the right side below the middle of the abdominal cavity, varies also in its form, muscularity, and relative size, and is provided with a thick, tough, coriaceous internal lining

as in other classes, to protect it from the hard shells and other dense substances taken in along with the food. This dense epithelium is easily detached after death, and is often found loose in the cavity of the gizzard. The muscles of the gizzard do not form a digastric mass as in gallinaceous birds, but commonly radiate from around a circular tendinous part (122. B. *d.* D. *b.*) on each side, as in crocodilian reptiles and rapacious birds, or pass continuously over the sides of the cavity. From the left side of the gizzard a passage, generally short and wide, leads to the third stomach (122. B. *e.* C. *c.* D. *c.*) which in the most common forms of naked cephalopods, as *octopus*, *sepia*, and *loligo*, has a convoluted spiral shape, and presents internally numerous transverse folds of its mucous coat. This third gastric cavity, which has thin membranous parietes and which receives the biliary and pancreatic secretions like the stomachs of other mollusca, is but slightly curved in the *sepiola* (122. C. *c.*), it forms an elongated simple stomach in the *loligopsis* (122. D. *c. d.*) where the spiral marking is almost confined to the anterior parietes of its pyloric extremity, and in the *nautilus* (122. B. *e.*) it forms a globular sac plicated internally, as usual, with parallel folds. It was mistaken by Swammerdam for the pancreas of the cephalopods. The intestine is short and wide in these rapacious animals, and is still destitute of cœcum-coli; the alimentary canal is no where imbedded in the substance of the liver as it is in many of the inferior mollusca, and it is not yet distinguishable into small and large intestine, as it is in most vertebrata. Passing to the left side from the third or spiral stomach, the intestine (122. B. *f. g.* C. *d. d.* D. *f.*) generally forms a short single convolution directed downwards near the left branchial heart, then ascends along the fore part of the liver to terminate between two longitudinal strong muscular bands near the base of the syphon, by a free anal orifice protected by two lateral valvular folds (122. C. *e.*) The rectal portion of the intestine in the naked cephalopods and the argonaute receives the excretory duct (122. C. *k.*) of the secreting follicular ink-gland (122. C. *h.*) near the anus, and this protecting, excrementitious anal gland appears to be wanting in the *nautilus* where the enveloping exterior shell sufficiently protects the animal without its aid. The ink-gland, which Monro mistook for the gall-bladder,

is covered by the hepatic lobules in *octopus*, in others, as *loligo*, it is free and anterior to the liver; and in others, as *sepia*, it lies behind the posterior end of the liver, but in none is it organically connected with that chylopoietic gland. The colour of its inky secretion is found to correspond with that of the coloured spots of the skin in the different species, and thus to serve as a more perfect means of concealment.

The liver is large and conglomerate in the cephalopods as in other molluscous classes, and is generally bilobate or quadrilobate in its exterior form. It is separable into four distinct lobes in the *nautilus* and the *loligopsis* (122. D. *g. g.*), and in most others it is more or less bifid at its lower margin (122. C. *f. f.*); and these lobes consist of numerous small aggregated lobules, the component *tubuli* of which, commonly filled with a reddish brown coloured turbid secretion, are short, wide, simple, and straight, like those composing the hepatic *acini* of the higher crustacea. This great chylopoietic gland occupies the anterior and dorsal part of the abdominal cavity, separated by its peritoneal covering from the œsophagus and anterior aorta above, and also by its muscular tunic from the gastric and circulating organs behind and below. As in other molluscous classes, it is destitute of a venous portal circulation and of a gall-bladder, as in them also it is supplied only by branches from the aorta, and its ducts open directly into the cavity of the stomach, not into the intestine as in the vertebrated classes. Its higher development in the cephalopods however is marked, as in the advanced development of this gland from its primitive *blastema* in the embryos of higher classes, by its greater separation from the contact of the alimentary cavity, and the consequent elongation of its ducts. The bile is poured into the third or spiral stomach by a single duct formed by the union of two or four ducts which descend from the lower and posterior part of the hepatic lobes; and the aperture by which the bile is conveyed directly into the cavity of the stomach, is here protected by two prominent valvular folds (122. D. *d.*), which are continued from the stomach along the side of the intestine towards the anus. Numerous small glands, sometimes in form of simple cellular follicles (122. C. *g.*) and sometimes forming lobules of ramified

tubuli (122. D. *e.*) encompass the hepatic ducts, and open into them by oblique valvular apertures directed downwards. These glands, which are common to the naked tentaculated cephalopods of both sexes, were mistaken by Swammerdam and Monro for generative organs, but by their structure and anatomical relations, they must be regarded as the analogues of the pancreas of other classes: they present vesicular enlargements at the ends of their *tubuli* like those of the pancreatic and salivary glands of most other animals, and part of their lobules sometimes terminate by separate ducts (122. D.) in the cavity of the spiral stomach. By the extension of the valvular folds (122. D. *d.*) from the entrance of the hepato-pancreatic duct along the course of the intestine, the secretions of these glands may also mingle with the food beyond the pyloric orifice of the stomach, as in vertebrated classes ; and in the empty and collapsed state of these parts the bile may pass along this valvular groove towards the anus without entering the stomach or duodenum in these carnivorous mollusca still destitute of a gall-bladder.

FIFTH SECTION.

Digestive Organs of the Spini-Cerebrated or Vertebrated Classes.

The high development of all the organs and systems of vertebrated animals, and the intricate constitution of all their tissues and fluids require a corresponding complexness in their digestive apparatus to produce those physical and chemical changes of the food which are necessary for its perfect assimilation to their complex bodies. Their alimentary canal is extended between the spino-cerebral axis and the heart, and terminates by distinct buccal and anal orifices without perforating the nervous axis. It is always provided with a distinct gastric enlargement, and with a large conglomerate liver, a spleen, and a pancreas. The hepatic and pancreatic secretions are always poured into the intestine below the pyloric orifice of the stomach, and the colon is generally distinguishable from the more narrow anterior portion of the intestine. The œsophageal portion of the alimentary

canal is shorter than the intestinal portion beyond the stomach, and numerous complicated salivary glands, which pour their secretions into the mouth, are rarely deficient in these classes. The chyle is now conveyed into the blood by a distinct system of chyliferous vessels. There are no gastric teeth, nor transverse maxillæ, and the atlantal extremities often assist in the prehension and division of the food. The jaws move in a longitudinal direction, and the teeth, when present, are confined to the buccal cavity, and most commonly the alveolar margins of the jaws. The differences presented by the digestive organs in the vertebrated classes relate chiefly to the nutritious quality, the consistence, and other properties of the food, and to the degree of development in the general organization of the body. The alimentary canal becomes more elongated, and the chylopoietic glands more complicated by the ramifications of their tubuli, as we ascend through the classes; but the canal is proportionably most elongated, capacious, and sacculated, in the phytophagous tribes, where the glands are also most developed, and the development and solidity of the masticating organs are proportioned to the resistance of the food and the mechanical division it requires to undergo in the mouth.

XIX. *Pisces.*—As fishes are mostly predaceous animals which swallow their prey entire, their œsophagus is short and wide, their stomach capacious, and their intestine short; their chylopoietic glands are moderately devoloped, and their teeth are generally in form of prehensile organs little adapted for mastication. The exterior of the mouth is sometimes provided with fleshy tentacular developments, like those of mollusca, as in the Lophius, Antennarius, Batrachus, and Cobitis, and the prehensile oral disk of many of the cyclostome fishes is furnished with sharp conical curved spines, like the arms of the *onychia* among the cephalopods. The dermal nature of teeth is most obvious in the fishes, where they develope successively and repeatedly during life from their cutaneous pulps over all parts of the mouth, like solid sheaths of cutaneous papillæ, and they are often arranged in a quincunx order, like hairs and feathers; they are mere osseous crowns of teeth, thinly covered with enamel, destitute of fangs, laminated, deciduous, and moveable on the surface of the

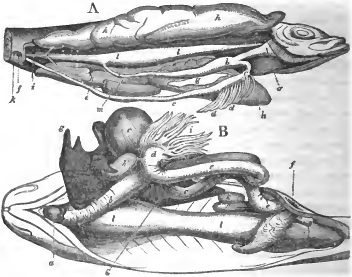
gums and other parts to which they adhere, till maturity, when they often anchylose to the bones beneath by the ossification of their pulp. They often adhere to the tongue of fishes as in many gasteropods and birds, to the vomer as in amphibia, to the palatine bones as in serpents, to the pharyngeal bones and the branchial arches, as well as to the maxillary and intermaxillary bones to which they become confined in the saurian reptiles and mammalia. The dermal teeth spread over the surface of the body in the acanthocephalous entozoa become in like manner gradually restricted to the mouth and jaws in higher forms of helminthoid and entomoid articulata. Some species of fishes, and of higher vertebrated classes, are entirely destitute of teeth; they are most commonly placed in numerous contiguous rows, and are frequently and variously renewed during life; they are sometimes confined to the jaws and lodged in alveoli, when the new teeth are developed behind and displace vertically the old, as in the crocodilian reptiles. These prehensile osseous hollow spines or fangless teeth of fishes are not opposed to each other so as to serve for mastication, but are most frequently placed alternately, and recurved as in serpents, crocodiles, dolphins, and most other predaceous non-masticating vertebrata, to check the escape of their prey or to tear it to pieces. The simple teeth are perforated for the blood-vessels and nerve, and expand over the pulp at their base. In many of the rays they unite to form continuous patiline plates covered with enamel, and in some osseous fishes the anchylosed bases of successive vertical teeth accumulate to form elevated cones continuous with the jaws. The teeth of the tetrodon succeed each other from behind, and the same is observed in the component layers of those of diodon which grow from interposed pulpy laminæ at their base. Where the food consists of very soft or minutely divided substances the teeth are sometimes wanting, as in the sturgeon, and they have broad strong crowns in those which break hard substances as the testaceous coverings of mollusca or crustacea.

The tongue, almost destitute of gustatory papillæ, is broad, short, and cartilaginous or muscular in fishes as in cephalopods, amphibia and many reptiles, and is often covered with teeth supported by the large hyoid bone, and

from the moist condition of their food, the liquid element they inhabit, and their want of masticating organs, they are generally destitute of salivary glands. The mouth is copiously provided with mucous follicles. From the want of means of dividing their food the œsophagus is short and wide to receive it entire, and is bounded below by the circular fibres of the strong cardiac sphincter. The œsophagus is often marked internally with regular longitudinal folds which greatly extend the surface of the mucous coat, and is sometimes also provided with rudimentary teeth, like the cutaneous spines often developed on the surface of the body. The rudimentary salivary glands appear to be most distinct where the pancreatic are least developed, and the increased size and number of the buccal muciparous glands generally compensate for the want of salivary glands in this class. A small valvular fold, or rudimentary *velum palati,* seen as low as the lampreys, and most developed above, as in the *zeus,* commonly assists in conveying the food and water backwards to the pharnyx, from which the water passes out freely between the branchial arches, and the food is directed to the œsophagus by the teeth of the pharyngeal bones, which are the most constant teeth of fishes and the most analogous to the gastric dental organs so common in the invertebrated classes.

The alimentary canal of fishes is generally more short and simple than in higher vertebrata, which accords with their predaceous habits and with their inferior position in the scale. With a short infundibuliform œsophagus, and a capacious gastric cavity with its two orifices approximated, the whole digestive canal of fishes is often shorter than the trunk, and passes nearly straight through the body, as seen in the herring, *clupea harengus* (Fig. 123. A.), where the narrow cordiac part of the œsophagus (123. A. *a.*) opens into a lengthened tapering stomach (123. A. *b.*) communicating by a long *ductus pneumaticus* (123. A. *m.*) with a large fusiform air-sac (123. A. *l. l.*), and where the wide duodenum (123. A. *c.*) provided with numerous pancreatic tubuli (123. A. *d. d.*) forms the commencement of a short intestine (123. A. *e. e.*) which opens into the cloaca (123. A. *f.*) anterior to the aperture (123. A *k.*) of the urinary organs and of the vas deferens (123. A. *i.*) from the testes (123. *h. h.*) of the male and the corresponding opening of the ovaries in the female.

FIG. 122.

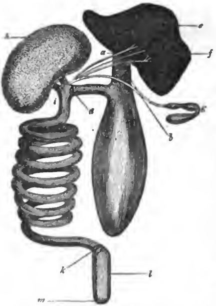


The œsophagus of fishes, surrounded by an exterior circular and an inner longitudinal layer of muscular fibres, and with a white villous plicated mucous coat provided with numerous distinct muciparous follicles, often terminates imperceptibly in the capacious stomach, and sometimes the pyloric end of the stomach passes insensibly into the duodenum, as in the short straight simple alimentary canal of the lamprey. The wide membranous cardiac portion of the stomach (123. A. *b.*) is commonly directed backwards as a simple closed sac, and the stronger narrow muscular pyloric part (123. A. *c.*) approaching in thickness to a gizzard, extends forward and to the right side. This gastric sac is sometimes globular as in the *lophius*, or extended backwards as in the *polypterus* and the *xiphias*; but the cardiac and pyloric orifices are almost always approximated, so that the food is retained as in a cœcum continued straight from the mouth. The muscular bands of the cardiac and pyloric sphincters are strongly marked, the pylorus is strengthened by a cartilaginous layer between the mucous and the muscular tunics, and the mucous coat around the pyloric orifice extends inwards to form a circular valve, with a fibriated margin, at the commencement of the duodenum as in many of the mollusca. The excretory ducts of the liver and pancreas enter the duodenum immediately beyond the pyloric valve, and the variously plicated mucous lining of

the stomach is abundantly perforated by the orifices of muciparous follicles. As in the invertebrated classes, the mesentery is often wanting or imperfectly developed in fishes, especially in the chondropterygii; the intestines are suspended by ligamentous bands which afford passage to the vessels, and the distinction of great and small intestine is scarcely perceptible, there being no cœcum-coli, and the colon preserving the same width and structure as the ilion, as seen in the annexed view of the chylopoietic viscera of the burbot, *gadus lota* (Fig. 123. B.) Immediately above the heart (123. B. *a.*) is seen the wide muscular œsaphagus (123. B. *b.*) passing backwards over the large lobes of the liver (123. B. *g. g.*) to the capacious stomach (123. B. *c.*) of this fish, and close to the pyloric valve the wide duodenal portion (123. B. *d.*) receives the ducts, rarely united in fishes, of the gall-bladder (123. B. *h.*) and of numerous pancreatic follicles (123. B. *i.*). The wide intestine (123. B. *e. e.*), after forming several convolutions below the large air-sac (123. B. *l. l.*), terminates in the fore part of the cloaca (123. B. *f.*) anterior to the common opening of the urinary organs and of the two ovaries (123. B. *n. n.*)

The mucous membrane of the stomach in this class commonly presents an irregular plicated surface, and that of the intestine is often plicated and villous, but without forming *valvulæ conniventes* like those of higher classes. At the part analogous to the *caput coli*, and where there is sometimes a small *cœcum* as in the *sole*, the mucous membrane passes inwards to form a free circular *valvula coli* which is often the only perceptible mark of distinction between the great and small intestine. The colon however is sometimes distinguished both by the presence of this circular valve and by its greater width, without either external longitudinal ligamentous bands or internal transverse folds, as seen in Fig. 124. which represents the digestive organs as I found them in the swordfish, *xiphias gladius*. The wide plicated muscular œsophagus (124. *a.*) here presents strong sphincter bands at the cardiac orifice (124. *b.*) of a long flask-shaped stomach (124. *c.*) with thick muscular parietes, especially at the narrow cylindrical pyloric portion (124. *c. d.*) Beyond the pyloric valve (124. *d.*) the three hepatic ducts (124. *f.*) from the liver (124. *e.*) and the cystics form an irregular lobed gall-bladder

FIG. 124.



(124. *g.*) open by a short common *ductus choledochus* into the duodenum, beside the large common opening (124. *i.*) of all the constituent follicles of this great reniform pancreas (124. *h.*) The long narrow small intestine (124. *i. k.*) forms seven convolutions on the right side and presents a distinct *valvula coli* (124. *k.*) where it terminates in the short straight colon (124. *l. m.*) wider than the rest of the intestine.

The pancreas presents every stage of the development of this important gland, as permanent adult forms in the class of fishes, consisting in some of mere folds of the duodenum of one simple tubulus in the *ammodites tobianus*, in others as the *lophius*, *chætodon longimanus*, *fistularia*, and *pleuronectes* presenting only two simple follicles or *appendicula cæcapylorica*, three in the *perch*, four in the *bream*, five in the *chætodon zebra*, some dozens in the *clupea* (123. A. *d. d.*) the *gadus* (123. B. *i.*) and most of the osseous fishes, and four or five hundreds in the *scomber Mediterraneus* where they open by six short ducts; these pancreatic follicles constitute a large reniform mass surrounded with a strong muscular tunic in the *xiphas* (124. *h.*) among the osseous fishes, and in the *sturgeon* among the chondropterygii; and in most of the cartilaginous plagiostome fishes they form a compact conglomerate gland, the component *tubuli* of which are nearly as fine as those of the liver and aggregated together into lobules and lobes. In some fishes, as the *centriscus*, no trace of this organ is perceptible. The large pancreatic follicles or appendicula pylorica of fishes, so variable in number

and size, and form, not only in the different species, but in the same individual, at different periods of its development, secrete a thick turbid fluid, not unlike the product of ordinary muciparous follicles, or those considered as rudiments of salivary glands; they are connected together by a loose cellular tissue, and numerous plexuses of vessels, and they admit the digested food of the intestine freely into their interior, like the biliary tubuli of many mollusca. The spleen is generally single, small, of various forms, attached to the side of the stomach, as in higher classes, largely supplied with lymphatics, and without perceptible duct; but in a few, as the *sturgeon* and the *shark*, it is divided into detached lobes, as in some of the cetacea; and in some fishes, as the *lamprey*, which has neither pancreas nor gall-bladder, nor mesentery, it appears to be wanting, as in the invertebrated classes. The liver attached to a tendinous diaphragm, is of great size, and of an elongated form, placed on the median plane, of a light colour, filled with an oily fluid, soft in texture like the spleen, deeply divided into numerous lobes, with the acini well marked, and the component tubuli comparatively large, provided with a portal and arterial circulation, and commonly with a large gall-bladder, as in other predaceous vertebrata. It is sometimes placed more to the left than to the right side; there are generally several long hepatic ducts, terminating separately in the lengthened cystic, several hepato-cystic ducts, entering the fundus of a pyriform gall-bladder, and the common *choledochus*, short and wide, opens along with one or more pancreatic ducts on the anal side of the pyloric valve. The activity of the secretions, and the muscular strength of the alimentary canal, effect a rapid assimilation of food in the short intestine of fishes; and they disgorge by the mouth the shells or other hard parts of their prey, like many predaceous animals of higher and of lower classes. The air-sac, or rudimentary lungs, generally communicates by means of a membranous trachea or *ductus pneumaticus*, with the intestine, the stomach, or the œsophagus; but however useful for progressive motion, or the transmission of sounds, it still contributes little to the aeration of their blood.

The form and extent of the alimentary canal of fishes and the condition of their chylopoietic glands vary as much as their

food which consists of everything organized in the rich element they inhabit. The rugæ of the mucous coat, which are sometimes longitudinal or transverse, or reticulate on the intestine of osseous fishes, form a remarkable continuous, elevated, spiral fold in the plagiostome chondropterygii, which winds round the interior of the canal, from the duodenum to the rectum. The rectum here terminates, as in other oviparous vertebrated animals, in a common cloaca, and has behind it in both sexes the opening, single or double, of the genital organs, the posterior part being occupied by the urinary passages. On the sides of the anus, in most of the cartilaginous and many of the osseous fishes, as in some aquatic reptiles, there are two oblique valvular openings, leading externally from the cavity of the peritoneum, and affording an easy exit to matters passing in that direction, but impeding their entrance from without. The peritoneum lining the interior parietes of the abdomen, and extending, like the pericardium above, over tendinous fibres of the diaphragm, has often the shining silvery lustre and white colour of the rete mucosum without; the mesentery is generally more developed in the osseous than in the cartilaginous fishes, and folds of the peritoneum, charged with adipose substance, sometimes hang from the outer margin of the intestine, forming a rudimentary epiloon. This imperfect condition of the mesentery in the lowest fishes, where the intestine is connected only by blood-vessels, approximates them to the invertebrata, and the same is often found as an abnormal character in man. The simple, straight, cylindrical form of the whole alimentary tube in many of the lowest fishes likewise assimilates them to the earlier conditions of the human embryo, as also the follicular character of their principal chylopoietic glands. As the umbilical vesicle in the osseous fishes passes entirely into the abdomen, to complete the intestine and the abdominal parietes by its mucous and serous coats, there can be no umbilical mark left in the adult, and there is no allantois communicating with the cloaca in the young, as they require no placental nutriment.

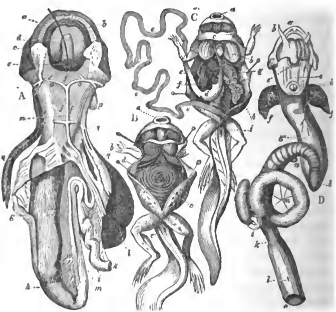
XX. *Amphibia.* The amphibious animals, like the fishes, are mostly predaceous in their habits, and swallow their prey entire, having loose and feeble articulations of the jaws, and sharp, slender, prehensile teeth, ill adapted for mastication. The teeth are placed sometimes, like those of fishes, in several rows on the palatine and both maxillary bones, as in

the *siren*, or more serpent-like in single rows on the palatine bones and both maxillæ, as in the *triton*, or only on the palatine bones and upper jaw, as in the *frog;* but they are wanting in both jaws in the *toad* and the *pipa*, although two small transverse rows are seen behind the posterior nares in the toad. The teeth have here the same osseous texture, thin coat of enamel, and feeble superficial attachment to the jaws as in most fishes, and these animals are almost as destitute of salivary glands as the permanent tadpoles of the sea. The long, free, and bifid tongue of the frog, covered with papillæ and muciparous follicles, more nearly approaches to the ordinary form of that organ in the serpents and many higher reptiles than the short, thick, fleshy form of the tongue common to the perennibranchiate amphibia and the toad. The strong muscular œsophagus, short, dilatable, and longitudinally plicated within like that of fishes, leads to a narrow elongated stomach, directed transversely from left to right. generally with thick fleshy parietes, especially at the pyloric portion, and covered above by the two lobes of a large liver, which is always provided with a distinct and free gall-bladder.

The stomach is most lengthened and narrow in the tadpole state of the higher amphibia, and in the adult forms of the aquatic species, as in the lower fishes and in the embryo condition of man, and these also exhibit the least distinction between the small intestine and the colon. In the young tadpole (Fig. 125. B. C.) of the common frog, which sucks with a small circular mouth (B. C. *a, a*,) the soft animal and vegetable matter of our fresh water ponds, the stomach (*c, d*,) is narrow and elongated, and the intestine (B. *c, d*, C. *e, e*,) of extraordinary length, and nearly equal throughout, is coiled up in a spiral manner, distending the capacious abdomen and perceptible through the transparent parietes. It is only slightly enlarged near the anus, and is attached to the vertebral column by an entire mesentery, as in the adults of all the amphibia. During the metamorphosis which so remarkably affects every internal system, and in which the soft and mixed food of the tadpole is changed for more nutritious aliment, as snails, worms, caterpillars, and similar creeping animals, the stomach and the whole alimentary canal become gradually shortened in their proportions, and their divi-

sions more distinctly marked, as seen in the annexed view of the digestive organs of the mature frog, (125. D.) At the base of the broad bifid, reverted tongue, (125. D. *b*, *e*,) is the short wide pharynx, (D. *c*,) and simple larynx leading to complicated cellular lungs, (D. *f*, *f*,) and the capacious muscular œsophagus and stomach, (D. *g*,) adapted to receive undivided prey, are bounded below by a constricted thick pylorus, (D. *h*,) beyond which the duodenum, (D. *n*,) is plicated internally with several transverse circular folds of the

FIG. 119.



mucous coat, like the *valvulæ conniventes* of mammalia. The form of the stomach is similar in the *toads*, *salamanders*, and *tritons*, and has the narrow elongated spleen loosely attached to its left side by cellular substance and vessels. A slight pyloric valve is seen in the toad and pipa. The two lobes of the liver overhang the stomach above and before; the intestine now forms but a few convolutions of inconsiderable width, supported by a distinct and vascular mesentery, (D. *m*) ; the pancreas, lengthened like the spleen, is situated behind the pylorus, and the short, wide, straight colon, (D.

l,) terminates in the cloaca, which receives also the openings of the urinary and genital organs, as in other oviparous vertebrata. The *valvula coli* is distinct in the frog, the hyla, and the triton. In the *pipa*, the liver has a small median or third lobe, and the lobes are more free, as in chelonia. In the great *menopoma*, (125. A,) of the North American lakes, there are palatine teeth, as well as superior and inferior maxillary, as in the nearly allied *tritons* and *salamanders*. The broad rounded fleshy tongue, similar to that of proteus and siren, exhibits at its base the small opening of a simple larynx, (125. A. *e*,) leading to the two long pulmonic sacs, (A. *q*, *q*,) and the wide infundibuliform œsophagus (A. *f*. *f*.), lying below the branchial veins (A. *o*, *o*,) and descending aorta, (A. *n*,) and above the heart, (A. *p*,) ends in a long narrow muscular stomach (A. *g*,), resting on the two lobes of the liver, (A. *l*,) and tapering to its thick pyloric portion, (A. *h*.) The commencement of the duodenum (A. *i*,), receives the end of a long ductus communis choledochus (A. *m*,), and pancreatic duct, and the intestine (A. *k*.), forms several convolutions connected by a distinct mesentery, before terminating in the cloaca. Most of the chylopoietic organs here, as in other perennibranchiate amphibia, partake of the elongated form of the trunk, as in the ophidian reptiles. The mucous lining of the intestine is raised into numerous longitudinal folds in the proteus, and also in the triton, the salamander, and the pipa; it forms quadrangular cells in the hyla, and transverse folds in the frog, and is more even in the axolotle. The liver is most numerously and deeply lobed in the caducibranchiate forms, as in the pipa and the frog, and most elongated and entire in the lower amphibia, as the axolotle, the proteus and the menopoma, and there is seldom a trace of pyloric valve between the opening of its duct and the stomach. The elongated stomach of the proteus passes insensibly into the duodenum, and is scarcely distinguished even by the usual constriction at its pyloric portion, but the gastric cavity is always marked in the amphibia by the great muscularity of its parietes when compared with the thin and delicate coats of the intestinal canal, and its form, especially in the higher genera, approaches closely to that of the chelonia.

An inferiority of character, or an approach to the class of fishes is thus seen in the digestive apparatus of the lower

amphibia, in the similarity and the extensive distribution over the buccal cavity of the small conical fangless teeth, the shortness of the tongue, the great development of the cornua of the os hyoides, the want of salivary glands, the shortness and width of the œsophagus, the elongated form and muscularity of the stomach, the similarity of the small intestine and the colon, the want of cœcum coli and fundus of the stomach, and the great size of the liver. In many of the animals of this class, however, we discover approximations to the higher vertebrata, in the more restricted distribution of the teeth, the elongation of the tongue and the body of the os hyoides, the greater distinctness of the gastric cavity, and its fundus, and of the small and large intestine, the absence of pyloric valve and valvula-coli, the development of transverse folds in the duodenum, and of a slight cœcum on the colon. The gall-bladder and the mesentery are now always developed, the pancreas is always conglomerate, and the tadpoles of all the species commence with the same short strait, simple alimentary tube as in the embryos of all the higher vertebrata, although some of them are destined to undergo a double metamorphosis in this part, to adapt it to the difference of food and habits of the larva and the adult.

XXI. *Reptilia.*—As most of the ophidian and saurian reptiles are carnivorous animals, and most of the chelonia phytophagous, there is great diversity in the form and structure of the masticating organs, the alimentary cavities and the chylopoietic glands in the different species of this class. The serpents, like most of the lower vertebrata, swallow entire prey, and have their teeth, like those of amphibia and the simpler fishes, in form of mere conical crowns, sharp, incurvated, unopposed to each other, attached to loose moveable bones, and adapted for prehension, not for mastication. The teeth of serpents are still attached to the palatine, pterygoid, and intermaxillary bones, as well as to the upper and lower jaws; they are wielded by powerful muscles, to enable them to wound and secure their prey, they are deeply imbedded in the soft gums, but rest in shallow osseous grooves; they are limited to single rows, as in higher vertebrata; the palatine rows are more constant in their characters than the maxillary; they are excavated by a large nutritious canal,

and the great anterior maxillary fangs of the noxious species are perforated and grooved on their fore part, to transmit the secretion of the poison gland. The scaly lips, and long, smooth, filiform, sheathed, bifurcated tongue, employed as an organ of touch, are little adapted to give the serpents acute feelings, from their food, which passes through their capacious dilatable mouth and œsophagus undivided. The salivary glands vary much in their development in different species, but the sublingual is always present, and two large superior and inferior labial glands send their secretions through numerous ducts. The large poison gland, (Fig. 74. *a*.), the analogue of the parotid, below and behind the orbit on each side, is confined to the noxious species: it contains a wide cavity, it is embraced by muscular fibres, and sends its long duct to the perforated base of the poison fang, (Fig. 74. *b*.)

The lengthened œsophagus, like the buccal cavity and the stomach, is susceptible of great distention, and in its collapsed state is longitudinally plicated; its thin elastic parietes are lubricated by the copious secretion of innumerable muciparous follicles, and it passes insensibly into the long, straight, and capacious cavity of the stomach, which can be distended with prey to many times the ordinary width of the trunk. The cardiac portion of the stomach is thin, membranous, longitudinally plicated, rarely presenting a sudden enlargement or a cœcal portion, and the posterior part of the stomach acquires thick smooth muscular parietes, and tapers to a narrow pyloric orifice, provided with a distinct internal valve and sphincter bands. Beyond the pyloric valve, which is seldom wanting, the duodenum, which presents a villous surface, receives the ducts from the liver, and the separate lobes of the pancreas, and the close narrow convolutions of the small intestine are compactly united together for protection, in a distinct tubular peritoneal sheath, to the commencement of the short, straight dilated colon, where there is commonly a circular projecting valve and sometimes a small cœcum. The short, straight, and wide colon ends in the cloaca, which receives the terminations of the two ureters, there being no urinary bladder, and of the two oviducts, or the two spermatic ducts; the single or divided male organ likewise passes out through the cloaca, as in other oviparous

vertebrata. The liver, the spleen, the pancreas, the kidneys, and the testes and ovaria present the same longitudinally extended form which is seen in the œsophagus, the stomach, and other parts of the alimentary cavity of the ophidian reptiles, and in the whole conformation of their trunk. The convolutions of the small intestine are not bound together in a sheath, but float freely, attached to the mesentery in the aquatic species of serpents, and in some of the higher sauroid forms, as the anguis. The large intestine is often sacculated by transverse constrictions approaching in form to valves, which divide its cavity, and still further delay the passage of the food through the ever active trunk of these animals. The liver is generally of a lengthened cylindrical form, not divided into lobes, provided with a distinct gall-bladder, and sends its secretion into the duodenum, near to the pyloric valve, where also terminate the several ducts from the lobes of the pancreas, which continue separate to their termination in the intestine, and the small spleen is here often compactly united to the pancreas by vessels and its peritoneal sheath.

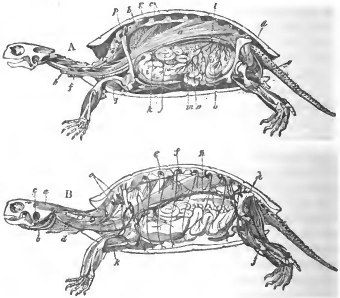
The saurian reptiles are mostly carnivorous, like the serpents, and swallow their prey undivided, and they present a corresponding short and simple alimentary apparatus; but as their trunk is shorter, and their abdomen is not habitually pressed on or dragged along the ground, they do not present the longitudinally extended form of the viscera, nor the modifications designed to protect the organs and check the rapid transit of the food, which we observe in the ophidian reptiles. The teeth are still merely prehensile organs, sharp, conical, recurved, similar in form, and placed alternately; but they are more fixed in their attachment by the outer alveolar margin of the maxillæ and by the gums; sometimes they are lodged in deep osseous alveoli, and are generally restricted to a single row along the margin of the jaws. Small teeth, in a few species only, are found also in the pterygoid bones, as in serpents; and, as in them, the tongue is generally long and bifid, and the salivary glands very imperfectly developed. The œsophagus, like the neck, is short and wide, and commonly leads to a narrow elongated stomach, placed from left to right, with its cardiac and pyloric orifices at the opposite

ends, and seldom presenting any cœcal portion to retard the food in its cavity. In the crocodilian family, where the teeth and the bones of the face are fixed, as in mammalia, and the tongue, as in these, is short, round, and fleshy, the stomach is in form of a round, strong muscular gizzard, with an anterior and posterior central tendon, from which muscular fasciculi radiate to the margins, as in many lower and higher animals, and the pyloric opening is guarded, as in many other saurian reptiles, with a distinct circular valve. The pyloric portion of the stomach presents a small cœcum, like that of a heron. The small intestine is comparatively long in a few vegetable-eating sauria, as the *iguana* and *scincus*, the flesh of which is edible, and it is shorter in the more carnivorous forms, and there is commonly a small but distinct round *cœcum-* as well as *valvula-coli* at the commencement of the large intestine. The cœcum-coli is large in *scincus* and small in the *lacertæ*, and the interior of the colon is often marked with longitudinal folds or quadrangular cells, but it is still destitute externally of the longitudinal bands which give this part a cellular form in the mammalia. The wide rectum terminates in the cloaca with the urino-genital organs, as in serpents, and the intestines are suspended freely by a complete mesentery. The peritoneum is often dark coloured or spotted, as in many other oviparous vertebrata, and the liver, more extended transversely than in ophidia, is always provided with a gall-bladder. The spleen is more distinct, and generally of a lengthened form, and the pancreas is less lobated in its exterior than in the serpents. The stomach being less extended longitudinally than in the serpents, the ducts of the liver are shorter, and the common choledochus enters apart from the pancreatic at a variable distance from the pylorus.

The chelonian reptiles subsist chiefly on vegetable food, and present a higher development of the alimentary canal, and of the chylopoietic glands than the more carnivorous ophidian and saurian species; and from the great length of the neck and the short and broad form of the trunk, the œsophagus is elongated as in ophidia, and the stomach, the intestine, and the liver are most developed in a transverse direction, as seen in the annexed views of the viscera of *emys europæa*

(Fig. 126. A. B.) The wide expanded jaws, covered with sharp horny sheaths, adapted to cut the coarse vegetable food, are moved by strong muscles, and the short, fleshy, undivided tongue is covered with long, delicate, sheathed papillæ, which are seen likewise on the upper part of the œsophagus. The mouth is abundantly furnished with muciparous glands, and the salivary glands, especially the submaxillary, are very differently developed in the different species. The long and muscular

Fig. 126.

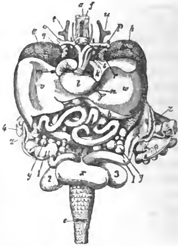


œsophagus is still wide, as in other reptiles, from the undivided condition of the food, and it presents internally numerous longitudinal folds of the mucous coat, which are seen also extending along the thin cardiac portion of the stomach. The longitudinal plicæ of the inner membrane are perceptible, though smaller, along the thick, muscular, pyloric part of the stomach. The stomach (126. A. *i.*) is extended transversely from left to right, of great strength and capacity, and behind the two expanded lobes of a large and broad

liver. The long papillæ which line the œsophagus are highly vascular, and are covered with a thin but obvious epidermic sheath. The thick, muscular, pyloric portion of the stomach sends inwards no circular fold, to constitute a pyloric valve, as we generally see at this part in the inferior vertebrata. The intestine is often more than six times the length of the trunk, and in the terrestrial forms, the colon presents a short, round, and wide cœcum, and a distinct circular valve at its commencement; but in the aquatic species the small intestine passes often insensibly into the colon, without either valve or cœcum. The colon is now generally distinct from the small intestine, long and wide, as in mammalia, but destitute of external longitudinal bands, and transverse corrugations, and the interior of the small intestine is generally marked by longitudinal folds or rugæ of the mucous coat, as in most amphibia.

The parietes of the alimentary canal are throughout muscular and wide, a character which we see likewise in the stomach, and which accords with the coarse vegetable food on which most of these animals subsist. The abdominal cavity is separated from that containing the lungs, (126. A. *g.*) by the peritoneum and the rudimentary diaphragm. The right lobe of the liver is much larger than the left, and between them is a small middle lobe; the gall-bladder is always present, and sends a short wide duct to open into the duodenum near to the pylorus; there is also a distinct hepatic duct, which receives that of the pancreas before entering the intestine. Although there are no valvulæ conniventes in the chelonia, the mucous coat of the intestine is of great extent, as in most other phytophagous animals, forming numerous longitudinal folds and cells, or tortuous rugæ, in its course, by which a greater extent of surface is afforded for the secretions, and for the distribution of the innumerable chyliferous vessels spread upon their alimentary canal. The annexed figure, (127) from Bojanus, presents a view of the viscera of the trunk, seen from the ventral surface in the *emys europæa*, where the wide muscular œsophagus (127. *a*,) behind the trachea (*f*,) and round thymus gland, between the right (*g*,) and left (*h*,) lung, and posterior to the three cavities (*i. k. l.*) of the heart, and to the

FIG. 127.



large right (*v*,) and left (*w*) lobes of the liver, passes to the left side, to terminate in the stomach (*b*,) which is here as transverse in its position as in the mammalia. The convolutions of the small intestine (*c*,) and the wide colon are seen between the developed ovaries (*y*. *y*,) and exterior to these, on each side, are the long and wide oviducts (1. 1. 4. 4.) with their expanded infundibuliform openings (*z*. *z*.) The rectum, (*d*,) as in higher vertebrata, descends to the cloaca, behind the ends of the oviducts (1.1.) and behind the large urinary bladder (*x*,) with its short urethra, and the cloaca receives also the openings of the two lateral sacs (2. 3.) before terminating in the transverse anal orifice, (*e*,) below the base of the tail. The alimentary canal has thus already acquired in the reptiles nearly all the divisions and typical characters which it presents in the highest of the vertebrated animals.

XXII. *Aves*. The alimentary apparatus of birds is adapted for the digestion of the higher forms of animal and vegetable matter, which their locomotive and prehensile organs enable them to obtain in the air, in the waters, and in the earth. The jaws have their alveolar margins covered, like those of chelonia, with horny plates, which vary in their forms, according to the kind of food, like the teeth of mammalia. The nearest approach to the teeth of quadrupeds is seen in the thin horny laminæ disposed along the sides of the bills in the *mallard*, and some other aquatic birds; and in the earliest condition of the birds the laminæ begin by a series of small detached tubercles, provided each with its pulp, its nerve, and its vessels, like the horny maxillary plates of the whale, and the more solid calcareous teeth of

other vertebrated animals. The broad depressed bills of ducks, geese, swans, and many other aquatic birds, with dentated edges, and soft sensitive lips, are well adapted for obtaining worms or other small objects under water or in mud, and they commonly present a well marked dental distribution of the alveolar nerves and blood-vessels, as well as a high development of the second and third branches of the trigiminal nerves. The flat spatulate jaws of the spoon-bills are adapted for quick lateral motion in the waters, and for extracting minute animals from the moist banks of lakes and rivers. The submaxillary pouch of the pelican serves as a net for seizing fishes; the straight sharp bills of cranes and storks dart with precision through the water upon their moving prey, and the long compressed bills of cormorants, gulls, albatroses, and many predaceous aquatic birds, terminate above in a sharp inverted hook, to seize firmly the smooth scaly bodies of fishes. The broad bills, with cutting edges, of the strutheous birds, are adapted to prune the leaves and shoots of plants, and the long narrow bills of woodpeckers to be inserted into small crevices to seize minute insects; and most of the insectivorous order of birds have a similar structure on a smaller scale. The long tubular beak of the humming birds is suited for insertion into the corollæ of flowers. In the grosbeaks and crossbills, the sparrows and buntings, and all the granivorous order, and in the larger gallinaceous birds the bills form stronger and shorter cones, broader at the base, to break down and remove the hard coverings of grains. In the climbing frugivorous cockatoos, parrots, and maccaws, the broad and powerful bills serve as prehensile organs, and to break the hard shelly coverings of seeds. The bills of eagles and vultures, hawks and owls, and other rapacious birds, are strong, short, compressed, arched, curved at the point, dense in their texture, and with sharp cutting edges, to seize, and tear, and cut the flesh of living prey. So that the forms of these external parts correspond with and indicate the structure of the internal organs of digestion, and afford useful zoological characters for the divisions of this class. The tongue, chiefly composed of a loose cellular texture, is here as variable in form and adaptations as the bill, or the claws, or the food, being long and filiform, like that of an ant-eater, in the woodpeckers, short and muscular

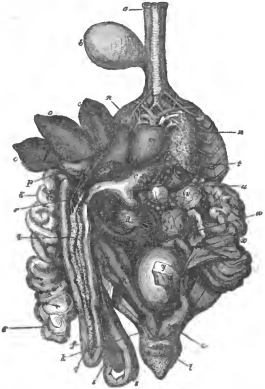
in the strutheous birds, arrow-shaped in the gallinacea, long, broad, and covered with large recurved spines in the swans, short, round and highly flexible in the cockatoos and parrots; but the body and cornua of the os hyoides are always comparatively long, slender, and flexible in this class.

As the food of birds is not masticated nor retained in the mouth, the salivary glands are smaller than in quadrupeds, more simple in structure, and commonly disposed in four pairs, one situate under the sides of the tongue, another at the junction of the rami of the lower jaw, another close to the base of the cornua of the os hyoides, and another at the angles of the mouth. The mouth is provided with numerous muciparous glands, and the salivary glands are most developed in gallinaceous and frugivorous birds, as in herbivorous quadrupeds. The closed ends of the *tubuli salivarii* are more or less dilated, as in other classes of animals, and the isolated vertical *tubuli* composing the first or sublingual pair open separately into the mouth by a row of pores. The second pair open by several ducts under the fore part of the tongue; the third, or submaxillary pair, open behind the second, sometimes by elongated ducts; and the fourth pair open within the angles of the mouth. The uvula, velum, and epiglottis, not being yet developed, the posterior nares and the larynx are but little protected, and the œsophagus, with a simple entrance, is here wide, muscular, and of great length, corresponding with the great length of the neck in birds.

As in other classes of animals, the whole alimentary canal of birds varies much in its length and capacity, and in the form and development of its cavities, according to the nature of the food, being long and capacious, with large glandular organs and muscular parietes, in the various phytophagous tribes, and with the reverse of these characters in those which feed more exclusively on animal food. The long, wide, muscular œsophagus, with a smooth mucous coat, and thin epidermic lining, passes down behind and a little to the right side of the trachea, as seen in the annexed figure of the viscera of the *gallus domesticus*, (Fig. 128. *a*,) and about the middle of its course, a little above the two anchylosed clavicles, it presents, in gallinaceous, raptorial, and many other birds, an enlargement, an *ingluvies* or crop, (128. *b*.) varying in form and structure according to the difference of the food, and

provided with numerous glandular follicles situate between the mucous and the muscular coats. Continuing downwards behind and a little to the right of the trachea, and behind the heart, (128.*m*,) and great branches of the aorta, the œsophagus passes forwards below the inferior larynx, between the two lobes of the lungs, (128. *n*. *n*,) and to the left side, to dilate into a

FIG. 128.



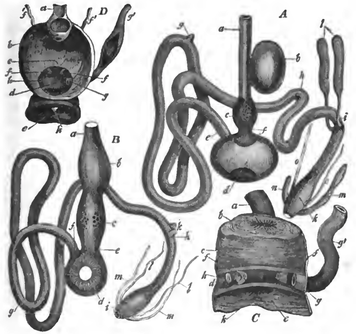
second gastric cavity, the glandular stomach, *proventriculus, infundibulum*, or *ventriculus succenturiatus*, (128. *c*,) which is highly vascular and provided with more numerous and larger follicles than open into the crop. Beneath the vertical infundibulum is the powerful muscular gizzard, (128. *d*.) disposed transversely from left to right, like the ordinary stomach of most vertebrata, covered with the lobes of the liver,

(128. *o. o. o.*) and lined internally with a more or less dense epithalium. This third cavity, the gizzard, lies in front of the ovary (128. *t. u. v.*) and oviduct, (128. *w. x. y. z.*) in the female, and of the testes in the male, and has its cardiac (*c.*) and pyloric (*e,*) orifices closely approximated to each other. The turns of the duodenum, (128. *e. f. g.*) on the right side embrace the conglomerate and lobed pancreas, (128. *q. q.*) which generally sends its secretion by two or more ducts, (128. *r.*) alternating with the separate ducts from the liver (128. *o. o. o.*), and the gall-bladder, (128. *p.*) The single, lengthened, and dark coloured spleen, (seen above *c. e,*) is attached near the left side of the glandular stomach, and the divided liver (*o.o.o.*) has generally a free gall-bladder (128. *p,*) placed under its right lobe. The intestine, (128. *g. h. k.*) is still shorter than in mammalia, but its different divisions are more distinctly marked than in the inferior classes. In young birds a remnant of the original entrance of the yolk-bag, or umbilical vesicle, is generally obvious in form of a small cœcal appendage on the anterior portion of the small intestine, and in many gallinaceous, wading, and water birds it remains through life. At the commencement of the colon (128. *h. k,*) which is here, as in lower oviparous vertebrata, of short extent, and generally neither wide nor sacculated, there are in most birds two cœca, (128. *h. i. i. s. s.*) of very various lengths and dimensions, extending upwards, and attached along the sides of the small intestine. The rectum, (128. *k,*) terminates in the general cloaca (128. *l,*) which receives also the ends of the two ureters, the openings of the pervious and impervious oviducts of the female, (128. *z,*) and of the vasa deferentia of the male.

The least constant of these digestive cavities, and the most variable in form, is the crop or *ingluvies*, the *cæca-coli* are likewise inconstant and nearly as variable in their extent of development and their form; the gizzard presents great differences in the thickness of its muscular and cuticular tunics, and the *ventriculus succenturiatus* in the development of its glandular follicles. The crop, which is here remarkable for its position in the neck, receives the unmasticated food, like the paunch of ruminantia, or the cheek pouches of many mammalia, and moistens it with the secretion of its numerous follicles. It forms a large globular sac, communicating by a

narrow neck with the fore part of the œsophagus in most of the gallinaceous birds, as represented in the annexed diagram, (Fig. 129. A. *b*,) and in the pigeons it is still larger,

FIG. 129.



and divided in front into two lateral sacs. The numerous follicles which open into its interior, become more vascular and enlarged at the time these birds are rearing their young; the milky secretion which they afford is very abundant in the crop of the pigeon, when feeding its young, and this is the only food they receive for the first two or three days after being hatched. The grains which have been moistened, softened, and partially digested in the crop, are brought up successively from that cavity and conveyed into the mouth of the young birds when they are further advanced. In the diurnal rapacious birds, (Fig. 129. B.) the crop (*b*,) forms only a general enlargement of the lower cervical portion of the œsophagus, into which entire prey is conveyed, and from which the hair,

claws, feathers, and other indigestible parts, are disgorged by the mouth, without being allowed to pass through the alimentary canal. This cavity however is entirely wanting in most of the passerine, wading, and palmified birds, although subsisting on the most dissimilar kinds of food; and it is scarcely perceptible in the nocturnal birds of prey, or in the long-necked struthious birds.

The glandular follicles on each side of the small ventriculus succenturiatus (129. A. B. *c. c.*) are mostly disposed in vertical rows, and have their orifices directed downwards. They are placed, like those of the crop, between the mucous and the muscular tunics; they are most numerous and complicated in the granivorous birds, where they form ramified tubuli; and they are simple elongated follicles in the birds of prey. They sometimes surround the whole cavity, or are confined to a part of the surface, and their copious secretion is required, to assist in digestion, from the deficient glandular structure of the gizzard itself. These glandular follicles of the ventriculus succenturiatus, or infundibulum, of birds are analogous in position to the cardiac glands, so large in the wombat, the beaver, and some other mammalia.

These muscular parietes of the gizzard (129. A. *d.*) form two strong digastric muscles, one anterior, the other posterior, with white shining tendons, in most gallinaceous and granivorous birds, and in many aquatic and other species. In most rapacious and carnivorous birds, the parietes of all the three gastric cavities are thin and highly extensible, and form almost one continuous stomach, (129. B. *b. c. d.*) with slight constrictions between its parts. The thin membranous gizzard however of these birds presents a distinct anterior and posterior central tendon, (129. B. *d.*) analogous to those of the two ordinary digastric muscles, (129. A. *d.*), and from which the muscular fasciculi, more or less developed in different species, radiate to the margins of the cavity. When this third gastric cavity is provided with strong muscular parietes, as in the gallinaceous birds, its internal epidemic lining forms a thick coriaceous dense coat, to protect the soft parts from laceration, and to enable them to act with effect upon their heterogenous contents. From the want of teeth in the mouth to act upon their hard food, these granivorous birds convey pebbles and other dense substances into their gizzard, to re-

duce their food, like the gastric teeth of crustacea, insects, many gasteropods, and other invertebrata; but in the carnivorous birds, with a thin membranous gizzard, no pebbles are swallowed or required, the activity of the secretions effecting all the necessary changes in the conditions of the food, aided by the high temperature, and the movements of the canal. From the proximity of the cardiac and pyloric orifices of the gizzard, it forms a sac open only above, and is not provided with the pyloric sphincter muscle, so common in other vertebrated classes. This free and wide pyloric orifice allows the food, partially digested in the three gastric cavities, and reduced by the muscular action of the gizzard, to pass out, in small successive portions, to the commencement of the duodenum. The small internal capacity of this strong grinding organ, which is chiefly filled with pebbles, necessitates the development of other gastric cavities between it and the mouth, to receive a sufficient quantity of coarse vegetable food for the maintenance of these large and heavy birds.

The *duodenum* forms a long narrow duplication embracing the bilobate conglomerate highly vascular *pancreas* (128. *q.q.*), the *tubuli* of which, like those of the salivary glands, commence with small vesicular enlargements, and terminate generally in two ducts which alternate with those from the liver and gall-bladder. The small *vitelline cæcum* (129. A. *g.*) which remains in several adult granivorous and wading birds, early disappears in the rapacious tribes (129. B.), and still earlier in the mammalia and in man. The two *cæca-coli* (128. *s. s.*) are likewise of greatest size in the gallinaceous and other granivorous birds, where they arise, like those of the *manis*, by two narrow canals (129. A. *i.*) from the commencement of the short *colon*, and enlarge into wide sacs (129. A. *l.*), often exceeding several times the size of the intestine, as in the *turkey*. They are very large in many of the palmipeds, as the swans, and they are connected by mesentery along the sides of the small intestine. In the ostrich they have a spiral fold of the mucous tunic extending through them, and several folds of the same membrane are seen in the upper part of the colon itself, which is here of unusual length. They have no analogy to the urinary bladder, which is below the rectal vestibule of birds, nor are they connected

with the cloaca; their duplicity is analogous to that observed in the crop of pigeons, and they are found double also in the *hyrax* and others among the lower mammalia. The *cœca-coli* are least developed in the grallatores and the nocturnal rapacious birds (129. B. *k. h.*), where they generally form two small projections on the side of the commencement of the colon. One of these only is developed in the herons, and in several birds, as in the lower vertebrated and invertebrated classes, and as in the plantigrade carnivorous mammalia, there is no cœcum-coli, especially among the zygodactylous birds.

The great intestine terminates in the dilatable *rectal vestibule* (129. C. *b*. D. *b*.), which is capable of being protruded externally through the cloaca and the anus. The distinction of the cloacal parts of the alimentary canal is most apparent in the ostrich (129. D.), where the *rectum* (D. *a.*) expands below into a dilatable vestibule (D. *b.*) which opens into the upper and back part of the *cloaca* (D. *c.*) This upper or first portion of the cloaca corresponds in birds with that which developes the urinary bladder and allantois in mammalia; and in the ostrich it serves for the retention of the urine as in the higher viviparous animals. At the lower and back part of this urinal portion of the cloaca, and separated from it by a slight ridge, are the papillar openings (D. *f. f.*) of the two *ureters* (D. *f.' f.'*), and exterior to these are the openings of the perforate (D. *g. g.'*) and impervious (D. *h.*) *oviducts* in the female, and of the *vasa deferentia* in the male. To this *urethro-sexual canal* (D. *d.*) which receives the ends of the urinary and genital organs, succeeds the *preputial cavity* (D. *e.*), the most exterior and posterior portion of the cloaca, which protects the organs of excitement in both sexes, the *clitoris* (D. *k.*) of the female and the *penis* of the male. These terminal parts of the digestive canal are perceptible in a less developed form in most other birds, and are represented in Fig. 129. C. as I found them in the female condor vulture, where the separation of the several portions is less distinctly marked. The wide rectum (C. *a.*) expands below into the rectal vestibule (C. *b.*), the highly vascular mucous coat of which differs much in appearance from that of the urinal portion (C. *c.*) of the cloaca, and is separated from the latter by a distinct circular ridge. The

limits of the urethro-sexual canal (C. *d.*) which receives the openings of the two ureters (C. *f. f.*) and the two unequal oviducts (C. *g. g.' h.*) are also perceptible; and on the median plain, in the dorsal part of the preputial cavity, is the opening of the *Bursa Fabricii* (C. *e.*), the analogue of Cowper's glands, and terminating in the same part as these glands in the mammalia. There being no placental attachment of the embryo of birds, the cloacal part of their alimentary canal is not extended outwards to form an allantois as it is in the embryos of quadrupeds.

XXIII. *Mammalia.* The digestive organs, like the general form, the internal structure, and the living habits of the species, vary more in the *mammiferous animals* than in any other vertebrated class, and they present the highest type of development in the various organs connected with this function; but the different forms of their alimentary cavities are most intimately connected with those of the masticating and prehensile organs, the organs of locomotion and perception, and more or less with all the other external and internal parts of their economy. The high development of their organs of sense, and the flexibility and softness of their sensitive lips and tongue, enable these animals to perceive minuter differences in the chemical and physical properties of their food. The solid structure of their teeth, and their fixed condition in deep alveoli of immoveable maxillary and intermaxillary bones, enable them more effectually to disintegrate their aliment, and to mix it with the secretions of the parotid, submaxillary, and sublingual glands, which are rarely deficient in this class. The teeth, formed in cutaneous sacs and successively renewed during life, are disposed in single rows, and have their forms regulated chiefly by the motions of the jaws which support them, and their texture by the nature of the food. They are rarely deficient as in the bird-like jaws of the *manis, myrmecophaga* and *echidna;* their place is sometimes supplied by horny laminæ as in the *ornithorhyncus* and the *whale;* sometimes they are simple, alternate, similarly formed, prehensile cones, as in several of the cetacea, but most generally they are distinguished by their forms and positions into *incisors, canine* and *molar* teeth, of which the last are most characteristic of the nature of the food. The molar teeth are renewed eight times in the *elephant,* the in-

cisors are shed twice in several *rodentia*, and most of the teeth are renewed once in the other orders of mammalia. Teeth are found in the lower jaw of the *whale* only in the embryo state, and they are confined to this part in the adult *physeter*. They are very deciduous in many of the *cetacea*, *edentata* and *cheiroptera*, only two are developed in the front of the lower jaw of the *uranodon*, the right upper incisor of the *monodon* remains undeveloped in its alveolus, the upper incisors are wanting in most ruminantia, and all the incisors are deficient in the edentata, excepting the six-banded *armadillo;* but in the extinct *anoplotherium* alone among mammalia, the three kinds of teeth formed an uninterrupted series around the jaws as in man. In most mammalia which feed on animal matter, the crowns of the teeth are covered entirely with enamel as they are likewise in the *quadrumana* and *man;* in the phytophagous quadrupeds, the enamel is generally disposed in tortuous or waved vertical laminæ, which extend transversely or longitudinally according as the motions of the jaws are longitudinal or transverse, as in most *rodentia*, *ruminantia* and *pachyderma*, and in many of the latter animals, as the *elephant* and *capybara*, several of the molar teeth are aggregated together by a solid external *crusta petrosa* to constitute a single compound masticating organ.

From the increased strength of the jaws, and the greater density and opposable character of the teeth, the temporal, the masseter, and other muscles of mastication are stronger than in the oviparous vertebrata, and from the lengthened form of the muzzle, the muscles of the lips are more separate and extended than in man, and produce more extensive motions of the lips. The long moveable fleshy sensitive lips, indeed, of most herbivorous quadrupeds serve them as hands to collect and crop their vegetable food. The long flexible tongue of the giraffe, the thumb-like process of the upper lip of the rhinoceros, and the elongated nose or proboscis of the elephant, are employed for the same purpose; and it is chiefly by their long vermiform lubricated tongue, that the ant-eaters secure their insect prey. The retraction of the highly moveable lips of carnivora serves to expose their sharp teeth for free action, and so to intimidate and weaken their prey. The numerous muciparous glands disposed

along the sides of the mouth in mammalia, which form large conglomerate buccal glands in several herbivora, assist the salivary glands in softening the food while thus delayed for mastication, and many species of *quadrumana*, *cheiroptera*, *rodentia*, and the *ornithorhyncus* have cheek-pouches, like the crop of birds and the paunch of ruminantia, to collect the food before mastication. The parotid, submaxillary and sublingual salivary glands, so generally developed in mammalia, are largest in herbivorous quadrupeds where the coarse food is longest subjected to mastication, less in carnivorous species where it is more quickly divided and swallowed, and least in the aquatic tribes where the thin limpid secretion of these glands is rendered less necessary by the moist condition of their food. The *velum palati* is more extensive than in the former classes; but the *uvula* is rarely developed, excepting in the highest quadrumana and man, and the cutaneous papillæ, so commonly spread over the tongue and palate, sometimes, as in the *monotrema*, acquire the density of spines in their cuticular sheaths, as they do in many birds. The tongue is supported by the short, broad body of the *os hyoides*, and sometimes a vermiform median fibro-cartilage, and the two pairs of cornua are most developed in the herbivorous quadrupeds, where the anterior pair reach the large styloid bones. The *os hyoides*, in its most perfect form, consists, as shown by Geoffroy, of twelve elements, the body of the bone being composed of a *glosso-* and a *basi-hyal* piece, the anterior cornua consisting each of an *apo-* a *cerato-* and a *styl-hyal* element, and the smaller posterior cornua containing each an *ento-* and a *uro-hyal* bone, and this complicated condition of the *os hyoides*, common in the ruminantia, is sometimes found as an abnormal form of that bone in man. But the *cornua*, in the normal state, are least developed in man and the orangs, and no trace of them is seen in the *manis*.

The pharynx of mammalia forms a distinct and wide cavity, and the long cylindrical œsophagus, corresponding with the length of the neck, never presents an ingluvial dilatation above the sternum, as it does in so many birds. The œsophagus is wide and dilatable in the carnivorous tribes, where the food is commonly swallowed in masses, and it is more narrow and muscular in the herbivorous quadrupeds, where

the aliment is more masticated and softened in the mouth. Its muscular tunic presents an exterior longitudinal, and an inner transverse layer of muscular fibres; the smooth mucous coat is seldom papillated or plicated, and is lined with a distinct epidermis which continues obvious over the three first cavities of the stomach of ruminantia. It sometimes passes much beyond the diaphragm into the cavity of the abdomen, and is surrounded by the outer layer of longitudinal cardiac fasciculi at its entrance into the stomach, where its mucous coat occasionally presents longitudinal or spiral folds. The œsophageal aperture of the diaphragm serves as a cardiac sphincter.

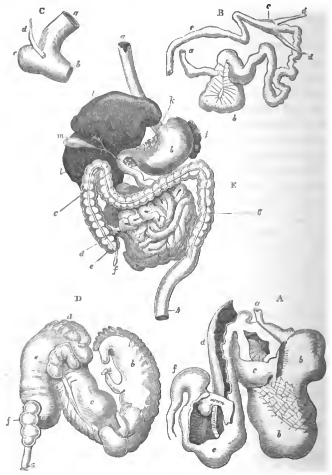
As the whole alimentary apparatus is most simple in the carnivorous mammalia, from the nutritious quality and the complex chemical constitution of their food, so their stomach consists generally of a simple globular sac, without internal subdivision or a cœcal portion, and the same form is seen in many insectivorous quadrupeds of different orders, as in monotrema, cheiroptera, insectivora, marsupialia. But where the food is of a coarser or more mixed character, the stomach becomes elongated transversely, and a cardiac fundus or cœcal portion is developed on its left extremity, as we find in many of the less carnivorous tribes, and in most of the quadrumana and man. In many of the rodentia, the thin membranous cardiac portion forms a considerable cœcum, and is partially separated by a constriction from the more muscular pyloric half of the cavity. The great development of the gastric glands around the cardiac orifice of the stomach in the beaver and the wombat, is required by the coarse vegetable food on which they subsist, and points out an analogy between this part and the glandular infundibulum at the cardiac orifice of the gizzard in birds. In several phytophagous mammalia, belonging to different orders, as among the pachyderma, masupialia, edentata, and even quadrumana, internal folds or external cœca divide the cavity of the stomach to a greater or less extent, and from the epidermic lining extending over the cardiac sacs thus formed, we observe a gradual transition to the complex stomachs of the cetacea and ruminantia, where the several compartments have different structures and functions. Although the uses and necessities of these different forms of

the stomach are sometimes obvious, they are often as little apparent as those of the enlargements developed on the intestine below that cavity; they have generally a relation to the digestibility and the nutritious quality of the food natural to each species. The pyloric valve, so common in the lower classes, is still often seen in this; the small intestine is more distinct from the colon in form and structure, and both are of greater extent than in other vertebrata; the *cœcum-coli* is single and more constant in its occurrence, and the rectum now opens externally by an orifice almost always distinct from that of the urinary and genetal organs.

Among the most complex forms of the gastric cavity of mammalia are those of many cetacea, where the food often consists of animal or vegetable matter in the lowest condition of organization. The œsophagus, like the neck, is short and wide, as in fishes, and commonly leads, as in them, to a large bottle-shaped longitudinal cœcal cavity on the left side, from which several successive smaller cavities extend transversely to the right extremity of this divided stomach. These successive gastric cavities are defined by very narrow constrictions, and by a difference even in the structure of their mucous membrane; and they are sometimes succeeded, as in the porpoise, by another sac developed on the duodenum. This multiple stomach accords with the imperfect means which most of the cetacea possess of masticating and salivating the food in the mouth, their teeth being mere prehensile organs, and their salivary glands being often entirely deficient. There is yet but little difference between the small and the large intestine; and the *cœcum-coli* is rarely developed in these animals. The ruminating quadrupeds, on the contrary, have the masticating and salivary organs most perfect, the œsophagus long and narrow, four gastric cavities with distinct functions, the intestine and colon long, capacious and distinct, and an enormous *cœcum-coli*. The œsophagus, as seen in the annexed figure of the stomach of the *lama* of Peru (Fig. 130. A. *a.*) enters directly into the first large cavity or paunch (*ingluvies*) (130. A. *b. b.*) placed on the left side, analogous to the crop of birds, and serving the office of the cheek-pouches of other quadrupeds. This capacious cavity is partially subdivided by large internal folds, and is lined with closs, small but

lengthened villi, covered with a thick epidermis. The same epidermic covering is continued distinctly over the second and third cavities. The second stomach or *reticulum* (130. A. *c*.) placed more anteriorly and to the right of the former,

FIG. 130.



is much smaller, and has its mucous lining elevated into reticulate folds forming polygonal shallow cells. This cavity also communicates with the œsophagus, and presents two

thick muscular valvular folds across the opening of communication, by the closing of which a canal is formed which leads to the third cavity of the stomach.

The paunch receives the crude-unmasticated vegetable food collected in large quantity while the animal is erect and grazing, and the process of rumination generally commences when this cavity is filled, and the animal is reclining at rest. In rumination, small portions of the unmasticated food, moistened and softened in the paunch, pass into the second cavity to be sent by its contraction, as a bolus, upwards through the muscular œsophagus to the mouth. After being thoroughly masticated and salivated in the mouth, the bolus returns, as a soft pulp, by the œsophagus; and, its stimulating quality being now altered, it finds the two valvular folds at the lower end of the œsophagus closed, and shortened by contraction, and is directed by the short canal they thus form, into the third, and thence into the fourth cavity of the stomach. The third or foliated stomach (*omasum*) is generally the shortest and smallest, though elongated and narrow in the *camelus* and *auchenia* (130. A. *d.*), and is provided internally with numerous longitudinal, alternately small and large folds, having their free margins directed to the centre of the cavity. The second and third cavities have their mucous membrane covered with small villi and distinct epithelium, like those lining the first stomach. The third cavity leads directly to the fourth or *abomasum* (130. A. *e.*) which is next in capacity to the paunch, lined with a soft highly vascular mucous coat, provided internally with large longitudinal folds, and apparently destitute of epidermic lining. The structure and form, and secretions of this fourth cavity, placed on the right side of the others, render it the proper digestive stomach, and the most analogous to the single digestive sac of carnivorous and higher quadrupeds.

In the camels, dromedaries and lamas, numerous rows of large, quadrangular, deep water-cells are developed on the parietes of the second stomach, and on the parts of the paunch next to that cavity. These cells are surrounded by muscular fibres which, by their contraction, are capable of excluding the food from the water-cavities; and by the gradual opening of the cells, the water is allowed to mix in successive small portions with the digesting aliment. These animals are thus enabled to convey and economise a large

supply of pure water, received at long intervals in the arid plains they inhabit. The second stomach is more appropriated to the retention of water than the large paunch, and receives it directly from the mouth, unmixed with the food, pouring over to the cells of the first stomach a quantity of the fluid when its own are filled. The third stomach (130. A. *d.*), which is here of a lengthened form, is provided both with longitudinal and transverse internal folds of its mucous coat, and the fourth cavity (130. A. *e.*) is of an elongated narrow form, curved suddenly towards its pyloric end (130. A. *f.*) and puckered like a colon. The fourth stomach of the ruminantia is the first developed, the largest, and alone employed for digestion, during the earlier periods of existence and during lactation. The milk, in suckling, passes down through the œsophagus to the closed valvular folds, which check its entrance into the first or second stomach, and convey it along the canal which they form, directly to the third or foliated cavity. The third stomach not having been yet distended with solid food so as to separate from each other its numerous contiguous laminæ, it merely forms a tube through which the milk passes into the fourth stomach; and thus the nutritious fluid of the parent is conveyed directly into the proper digestive stomach of the suckling ruminant, without being accumulated or retarded in any of the previous cavities.

The intestinal canal of the ruminantia is of great length, being sometimes more than thirty times the length of the trunk of the body, as in the sheep, and the colon is always long, convoluted, and of great width compared with the small intestine. The long narrow small intestine has generally thin membranous parietes, a villous internal surface, and a short mesentery to suspend its numerous convolutions from the vertebral column. The *cœcum-coli* is long, wide, and, like the colon itself, has smooth internal parietes. The colon is not here puckered and sacculated by longitudinal bands as it is in many herbivorous quadrupeds, and forms numerous long convolutions before it descends on the left side to terminate in the rectum. The liver is more deeply divided into lobes than in the cetacea, but less than in most carnivorous quadrupeds; many have a large and elongated gall-bladder, while others, as the camels and deers, are destitute of this reservoir; the gall-duct, whether from the liver

or gall-bladder, commonly receives the single duct of the bilobate pancreas near its entrance into the duodenum, and the long flat spleen is attached to the paunch.

Although the pachyderma do not ruminate, their kind of vegetable food, the structure of their masticating and salivating organs, and the general characters of their alimentary canal, approach the nearest to those of ruminantia; but as they masticate and salivate their food before it is first swallowed, they do not require the arrangement of gastric cavities given for this purpose to the latter animals. The solidungulous pachyderma have, therefore, only the fourth or true digestive stomach of ruminantia, a single undivided elongated sac, without internal partitions or external constriction, but they have the same lengthened narrow small intestine with an internal villous surface, the same large cœcum-coli, and the same long wide convoluted colon. Their colon and its capacious cœcum are rendered puckered and sacculated by the usual three longitudinal bands of muscular fibres. They have no gall-bladder, and their hepatic duct opens, by a common orifice with the pancreatic, within four inches of the pylorus. The stomach is as simple, though more elongated in form, in the *elephant* and *rhinoceros*, but is slightly tripartite by two transverse constrictions in the American *tapir*, and is still more deeply divided internally in the *pecari* and other forms of the hog tribe. The strong muscular œsophagus of the *pecari* enters the middle large cavity of the stomach, the left portion of the stomach forms a great crescentic cavity terminated by two cœca, and the wide pyloric portion is partially detached by the internal extension of the mucous coat; but the mucous coat, as in other pachyderma, has nearly the same characters over all the partially detached gastric cavities. The stomach of the hyrax is divided by a narrow contraction into two almost globular sacs, the first of which is lined with epidermis not perceptible on the second, and the commencement of the duodenum is enlarged to form a smaller third sac; the intestine and the colon are nearly of the same length, and the *ilium* (Fig. 130. B. *a*) terminates in a large irregular sac, which is the ordinary *cœcum-coli* (130. B. *b*); the commencement of the colon forms also a wide elongated cavity, and about the middle of its course this irregular colon forms another enlargement,

(130, B. *c*), from the sides of which two small tapering *cœca* (130, B. *d*) are extended, as from the colon of most birds. The transverse *valvula coli* is seen at the entrance of the *ilium* into the first wide *cœcum*, but the second tapering *cœca* are without valves. The two *cœca-coli* are seen also in the ant-eater and the lamantin, but are placed at commencement of the colon in these animals; they are small, without valves, and with narrow contracted openings in the *myrmecophaga*, as in birds. The stomach of the *myrmecophaga*, like that of *echidna* and *ornithorhyncus*, presents the simplest undivided form of this cavity, but is more strong and muscular, like the gizzard of a bird or of a crocodile, to compensate for the want of teeth. In the *sloths* the left half of the stomach is sacculated by internal partition like that of *semnopitheci* among the quadrumana, and its pyloric half is puckered and spirally convoluted like that of a *kangaroo*.

Among the diversified forms of marsupialia, the carnivorous *dasyuri* and the insectivorous *didelphes* and *perameles* have a membranous stomach and a short alimentary canal, like the dentated quadrupeds of similar food belonging to other orders. In the kangaroos the stomach (130, D.) is almost as complicated as that of the ruminantia, which they represent in Australia, and which they can partially imitate in the rumination of their food; it is spirally convoluted, deeply divided by transverse contractions, lined with epidermis, puckered by three longitudinal bands like the colon of pachyderma, sacculated by large cells (130, D. *d*) developed from its sides, with a tapering winding cœcum (130, D. *b*) nine inches long, extending to the left of the cardiac orifice (130, D. *a*), and provided with two rows of large glands opening into its pyloric portion. The stomach is nearly similar in the *hypsiprymnus*, but less lengthened and divided, and with the gastric glands disposed in a single lengthened narrow mass on the left portion of the cavity. The intestine of the kangaroo corresponds in its great length and convolutions with the coarse vegetable food, and the cœcum-coli is about fifteen inches in length. The cœcum-coli of the wombat (130. C.), a marsupial rodent with some affinities to the beaver, forms a short and wide cavity (130. C. *c*.), and has a remarkable small narrow appendix (130. C. *d*.) opening by a valvular orifice close to the termination of the

ilium (130. C. *a*.) in the colon (130. C. *a*.) resembling in form the appendix vermiformis of man and the highest quadrumana. At the cardiac orifice of the stomach in the wombat, as in the beaver, there is a large and complex gastric gland, forming a close analogy between this part and the glandular infundibulum of birds, and especially required in these quadrupeds from the very coarse nature of their food.

The high development of all the organs of relation in carnivorous quadrupeds, enables them to select and obtain the kind of food which requires least elaboration from digestive organs for its assimilation to their body; and their salivary, muciparous, and other chylopoietic glands, are comparatively small; their œsophagus wide from their imperfect mastication, their stomach, simple, small and membranous; their intestine short and narrow; the colon small, and the cœcum-coli very short and narrow, or entirely wanting. The villi of their long muscular tongue acquire often the density of spines, the thick muscular fasciculi of their strong œsophagus have often a spiral course round that wide tube; the soft mucous lining of their membranous stomach presents no perceptible epithelium, and all trace of the ordinary *cœcum-* and *valvula-coli* has entirely disappeared in the plantigrade forms of these animals. The deeply lobated liver of the carnivora is always provided with a moderate gall-bladder, which sends its duct into the duodenum at a very short distance from the pylorus. The spleen has commonly a lengthened narrow form with numerous round white internal corpuscules, and the two unequal lobes of the pancreas are subdivided into smaller distinct lobules, which pour their secretion into the duodenum, generally by two separate ducts, a little beyond that of the gall-bladder.

The surface of the free and lengthened tongue of the insectivorous bats, is likewise often provided with firm and sharp spines, and their stomach, like that of most carnivora, quadrumana and man, forms generally a simple membranous globular or pyriform sac, with a small cœcal portion to the left of the cardia; but in the frugivorous *pteropi*, as in the more elevated *semnopitheci*, the stomach forms a capacious lengthened saculated cavity, puckered and winding like the colon of a herbivorous quadruped or the stomach of a kan-

garoo, and corresponding, as in these, with the inferior quality of the food.

The typical forms and characters of the human digestive apparatus (130. E.) are gradually developed and established in the diversified order of quadrumanous animals. The cheek-pouches, so frequent in the inferior mammalia, and so general in the simiæ of the old continent, and which are mere extensions of the thin parietes of the mouth outwards and backwards over the ramus of the lower jaw, covered and moved by numerous fasciculi from the *platysma myoides* and the *buccinator* muscle, are already lost in the orangs as in man; the rounded tubercles of the molar teeth, common to the higher quadrumana and man, accord with the softer condition of the food natural to these two tribes, and the uvula and velum palati are most developed in our species. The muciparous labial and buccal glands, which soften the contents of the cheek-pouches, are more constant and larger in man; but the parotid, submaxillary, and sublingual salivary glands, appear to exceed the human in the more frugivorous forms of quadrumana. The shortness of the œsophagus (130. E. *a.*) corresponds with that of the neck, and the elevated position of the head, in the quadrumana and man; its muscular fibres form an inner transverse and an exterior longitudinal layer, in place of the opposed spiral fasciculi of inferior mammalia; and it enters the stomach (130. E. *b.*) at the shortest distance beyond the pillars of the diaphragm. The stomach is less elongated transversely, and less generally constricted in the middle, in the quadrumana, than in man, but the cardiac cœcum is most developed in the former, and especially in the lowest tribes, where also the most lengthened form of the mesentery suspends the convolutions of the intestine. The human *valvulæ conniventes* are still wanting in the duodenum; but the *glandulæ Peyeri* are often much more numerous, and more extensively spread over the intestine, than in man, where they are confined to the lower part of the jejunum and ilium. The duodenum (130. E. *c.*) receives the secretions of the liver (130. E. *l. l.*) and pancreas (130. E. *h.*) by a single orifice of the united ducts, in the simiæ, as in man. The gall-bladder (130. E. *m.*) is always present, the liver is more deeply lobated in the lower quadrumana, and the spleen (130. E. *i.*) has generally a more

lengthened or crescentic form, but a smaller bulk, than in man.

The colon is most lengthened, smooth, convoluted, narrow, and even in its parietes, in the lowest lemurs, and becomes shorter, less convoluted, much wider, and more sacculated in its parietes by longitudinal muscular bands, in the higher simiæ and in man (130. E. *e. g.*) The cœcum-coli, which is always present, is, like the colon, more narrow, curved, smooth, and lengthened in the lemurs, where it sometimes exceeds a foot in length; it is more short, straight, rounded, wide and cancellated, in the simiæ and man (130. E. *d. e.*), and in several of the highest genera it is already provided with the *vermiform appendix* (130. E. *f.*) so characteristic of the human intestine. This narrow glandular appendix is the first cœcum developed in the human embryo, and is the form presented by the adult cœcum in many of the inferior mammalia. So that while all the essential parts of this complex apparatus of organic life pass through innumerable phases of development in ascending through the various grades of the animal kingdom, all their diversified forms are alike perfect in their adaptations to the living conditions of the species, and man and the monad, at the two extremes of this great series, are alike digestive sacs, moved to and fro in quest of matter to prolong individual existence and that of the race.

CHAPTER SECOND.

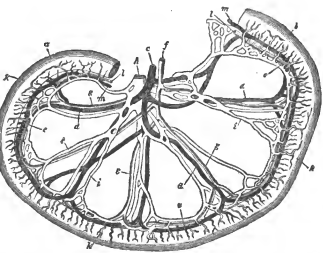
CHYLIFEROUS SYSTEM.

The assimilation of foreign matter to the textures of the body is comparatively a simple process, and effected by the simplest means, in the lowest tribes of animals, where there are few elements in the food, and few in the textures into which it is to be converted; so that the same alimentary cavities which receive and digest the food, transmit the assimilated portion through their parietes, to form part of the homogeneous tissue of their body. This low condition of development may exist in the simpler forms of poriphera, polypiphera and acalepha; but in tracing the progress of the digestive cavity through all its metamorphoses and grades of development in the animal kingdom, we have seen it become more extended and complicated, more finely organized, and divided into distinct parts with distinct functions, as we ascend in the scale; follicles, cœca, tubuli, glands, and vessels, develope from its sides, and become more or less distinct in connection and function; a sanguiferous system thus becomes isolated and developed, to extend the source of nutriment to each point of the body, and the nutritive fluid of this complex hydraulic apparatus, is received from the alimentary canal, directly by the veins, in most of the invertebrated classes. In all the higher animals, however, constituting the vertebrated division, a distinct system of vessels is employed to receive, and still further to elaborate, the fluid product of digestion, and to convey it to the venous system. The fluid which these vessels take up from the intestine, being generally opaque and of a whitish colour in quadrupeds, has received the name of *chyle* or lacteal fluid, and the vessels, plexuses, glands and ducts, through which it passes in its way to the blood, constitute the *chyliferous system*, which like other complex systems, presents

diversities of character, and grades of development in the different classes.

From the white serous condition of the blood in the invertebrated classes, resembling the limpid transparent chyle of the oviparous vertebrata, several parts of the former animals have been taken for their chyliferous system, as the mesenteric veins of *echinoderma* by Monro, the radiating prolongations of the stomach of *medusæ* by Carus, the biliary tubes of insects by Sheldon, and even the nervous system of *conchifera* by Poli. In the red-blooded animals it is easy to distinguish, by the difference of colour, size, structure and mode of ramification, the numerous plexuses of chyliferous vessels spreading upon the intestine or between the folds of the mesentery, as seen in the annexed view (Fig. 131. *h. i. k.*) of those of the small

FIG. 131



intestine of the tortoise. They accompany the veins (131. *c. d. e.*) and the arteries (131. *f. g. l.*) in their course along the mesentery to the thoracic duct (*h.*); but much exceed in thickness, in number, and in the frequency of their anastomoses, the blood-vessels which they accompany. The opaque white colour of their contents, and their passage through the mesenteric glands, render their distinction from

the red blood-vessels still more obvious in the mammiferous class.

The chyle contained in these vessels in the vertebrated classes, and derived from the digested chyme of their alimentary canal, much resembles the white blood of the lower divisions of the animal kingdom, and varies in its composition and properties in the different tribes of animals, and in the same animal according to the kind of food on which it subsists, being most allied to red blood in the reddish colour, and the abundance of its fibrinous crassamentum in the highest animals, and those which subsist on the most nutritious animal food, and most remote from that condition in its pale and limpid character, and the great proportion of its thin serum in the lowest fishes, and the most impoverished animals. The light floating white coloured fatty globules, seen already formed in the chyme, appear also to have the same relations to the chyle as to the circulating mass of blood, in the different tribes of animals and in the different conditions of their food. The elements of this fluid are intimately mingled in passing through the chyliferous vessels; but their motions are not aided by pulsating ventricular sacs, like those developed on the lymphatics in situations where their fluids are less affected by the movements of the surrounding parts.

The same grades of development which are perceptible in the properties and constitution of the chyle, are seen also in the structure, forms and number of the vessels which convey it in the different vertebrated classes, being fewer in number, destitute of internal valves, and apparently composed of a single tunic in fishes, while in the class of mammiferous animals, their numbers exceed all calculation, their valvular structure is most universal and complete, and their two component tuncis are easily separable from each other. The inner coat is a thin, smooth, serous membrane, which, by extending more or less in free folds into the tubular cavity of the vessels, produces the crescentic or semilunar valves, so numerous and important in the higher animals, in directing the motions of the contained fluid constantly towards the receptaculum chyli or the thoracic duct, these motions being derived chiefly from the *vis a tergo* of the newly absorbed chyle, and the incessant movements of the blood-vessels and the surrounding viscera of organic life. The exterior tunic is a

tough, thin, fibrous layer, destitute of irritability, and the strength and elasticity of which, allows of great distention of the vessels without rupture of their delicate parietes.

The chyliferous vessels of *fishes* not only appear to consist of a single tunic, destitute of valves, and without those conglomerate glands which they form in higher classes; but they are fewer also in number on the intestine, and between the folds of the mesentery, and contain a more thin limpid and colourless chyle, with less proportion of fibrin, and without oily globules. They are obvious in all kinds of osseous and cartilaginous fishes, spreading on the mesentery, and forming two layers on the coats of the intestine, composing reticulate plexuses between the mucous and the muscular tunics, and also more exteriorly between the muscular and the peritoneal coats, where they continue along the course of the mesentery. They appear to originate in the highly vascular erectile villi, so commonly developed from the mucous lining of the small intestines of vertebrated animals, and which extend freely into the fluid periphery of the chyme passing through the alimentary canal. The chyliferous vessels of the intestine anastomose freely to form numerous loops and plexuses in their course, and constitute by their union larger and larger trunks, which pass on between the folds of the mesentery to terminate in one or two dilated reservoirs or *receptacula chyli.* The only trace of the mesenteric glands, (found on these vessels in many higher animals) are seen in the tortuous ramifications and complicated anastomosing plexuses which they often form in fishes, in their course towards the general receptacle of the chyle; and indeed this the true constitution, though on a simpler scale, of the so-named mesenteric glands of the highest animals and man, which have never the structure or excretory ducts of true glands. Two *thoracic ducts* proceed forwards from the *receptaculum*, and form also frequent unions by their astomoses, as they proceed forward along the sides of the aorta, to open into the branches of the superior and inferior *cavæ* or the jugular veins. These vessels, like the lymphatics, appear to have communications with the veins, which accompany them, and semi-lunar valvular folds are developed at the orifices by which they communicate; and although, by injection, and by inflating air upon the inner surface of the

opened lacteals, we perceive that they are still destitute of the internal folds, which form the valves throughout their whole course in higher classes, they already present a sacculated or beaded appearance when injected, from numerous small constrictions like rudimentary valves. Two or three small lenticular glandular bodies, seen in some fishes as far forward as the œsophagus, appear more analogous to a thymus than to chyliferous glands.

The trunks of the chyliferous vessels communicate with the trunks of the lymphatics, as the lymphatics communicate with the trunks of veins, or as the ducts of chylopoietic glands communicate with the alimentary canal; but the dissimilarity of function is equally obvious in the several parts thus connected with each other. The lacteals from the intestine, and the lymphatics from the posterior parts of the body, generally unite to form two great trunks before they enter the *receptaculum*, and this reservoir formed by their union, whether single or double, is comparatively very large in fishes. The two thoracic ducts, before entering the internal jugular veins, receive the lymphatic trunks from the head and fore part of the body, and they form several loops and plexuses by their frequent anastomoses in this place; and indeed the two thoracic ducts, whether they originate from a single or double receptaculum, communicate with each other in the freest manner, by lateral unions, throughout their whole course. The capillary lacteals exceed in diameter the capillaries of the blood-vessels, and in the frequency of their anastomoses throughout their course they much exceed the veins, which surpass the arteries in this character.

In the *amphibious* animals the chyliferous system is nearly in the same condition of development as in fishes, being still destitute of valves and mesenteric glands, and conveying only a thin limpid chyle, like the fluid of lymphatics, from the intestine to the blood. They appear to have a similar origin and distribution on the intestine; they follow closely the course of the blood-vessels, and form the same anastomoses and plexuses on the expanded mesentery of these animals, as in fishes. Their wide reservoir formed by the union of their trunks, sends forward two thoracic ducts, to terminate in the jugular veins, with the trunks from the anterior pair of lymphatic hearts. Although the lymphatic pulsating cavities,

which collect the lymph from the external parts of the amphibious animals, and propel it into the veins, appear to be extensively developed in the oviparous vertebrata, no similar moving powers are observed in the course of the chyliferous vessels, which occupy an internal position, the most exposed to the influence of incessant movements from the surrounding parts. The great tenacity of life and irritability observed in these anterior and posterior lymphatic hearts of the amphibia, which continue to pulsate long after the animals are cut to pieces, is analogous to the permanence of vitality observed in the chyliferous vessels even in the higher classes of animals, where they continue to absorb chyle from the intestine long after apparent death.

Most parts of the chyliferous system present a higher grade of development in the *reptiles*, which is most apparent in the existence of distinct valves in the trunks and larger branches of these vessels, and in the white milky condition of the chyle from the abundance of its globules in the carnivorous crocodilian family. They are still, however, without mesenteric glands, their valves are less perfect in their structure and function than in birds and quadrupeds, and allow injections to pass easily against their course; the chyle is still colourless in most of the serpents, lizards, and tortoises, and the ramifications of the lacteals (131. *h.*), closely accompany those of the veins (131. *c. m.*) and arteries (131. *f. l.*) both on the intestine (131, *a. b.*), and between the folds of the mesentery. The coarse vegetable food of the chelonia, and the consequent great length of their intestine, give occasion for the numerous large chyliferous vessels which cover their alimentary canal and mesentery; and from the very imperfect development of their valves, and the consequent facility with which injections pass from trunks to branches, these animals present peculiar advantages for illustrating the structure and functions of this system. Besides forming numerous reticulate plexuses by their anastomoses on the intestine, and along the course of the mesentery, the analogues of higher and more complex chyliferous glands, (131. *h. i. i.*), the trunks of these vessels, by their frequent inosculations, constitute a continuous series of arches along the entire outer margin of the mesentery, much exceeding in number those formed in the same situation by the veins and arteries. The

union of their trunks form a large elongated irregular reservoir, from which proceed two or sometimes more anastomosing thoracic ducts, which form almost a continued plexus by their frequent unions, as they proceed forwards along the left branch of the aorta, to the anterior part of the trunk, where they terminate in the jugular or the subclavian vein, or in the angle of union between these vessels. The frequent unions, and the great multiplicity of chyliferous vessels in all vertebrated animals compared with the arteries or the veins, are rendered necessary by their imperfect means of propelling their contents, and by the variable pressures to which they are subjected. From the approximation of the crocodilian reptiles to the carnivorous mammalia, in structure, food, and habits, they already exhibit a larger proportion of fibrinous globules, and a more sanguineous character of their chyle, than have been observed in other reptiles. During the active feeding season of the chelonian reptiles, their lacteals are found turgid with chyle, which can be pressed forwards, in large quantity and repeatedly, from capillaries to trunks, and from trunks backwards to capillaries, in the opened bodies of these animals, so remarkable for their tenacity of life. So frequent are the anastomoses of the several thoracic ducts, which form a plexus round the aorta in the tortoise, that when inflated with air, they entirely cover and conceal that vessel. Before entering the veins, these ducts receive the lymphatic trunks from the head and arms, but no anterior lymphatic hearts are seen, although they are seen on the posterior lymphatic trunks of many reptiles.

The coats of the chyliferous vessels are still very thin and distensible in *birds*, and their valves, which are more abundant on the trunks and branches than in reptiles, are still so incomplete as to allow injections to pass freely against their course, from trunks to capillaries; and although conglomerate glands are already perceived on the lymphatics, especially in the neck, no similar glands are yet developed on the lacteals of the mesentery. The chyle is still limpid and colourless, as in the cold-blooded vertebrata, and the more conglomerate glands of quadrupeds are still represented by simple plexuses of lacteals between the folds of the mesentery, in this warm-blooded oviparous class. The lacteal vessels are now more crowded in layers below the serous and above the

mucous coat of the intestine, they appear more obvious, and have more symmetry in their distribution. Their trunks unite with those of the lymphatics, to form a more regular receptaculum, from which two thoracic ducts, with fewer inosculations, advance forwards to terminate by several openings on each side of the neck, at the junction of the subclavian and jugular veins. This duplicity of the thoracic duct, so general in the lower vertebrata, is occasionally found as an abnormal character in man, when they are observed to proceed upwards on each side of the aorta, to terminate one in each of the subclavian veins. The lacteals, like the lymphatics, thus accompany or envelope the trunks of arteries, to profit by their constant pulsations, in forwarding their contents to the veins, and their common trunks terminate in the subclavian or jugular veins, as the most convenient place near the heart and the lungs, throughout the vertebrated classes.

The chyliferous, like the lymphatic system, is more isolated from the sanguiferous in the *mammalia* than in the lower classes, and it manifests a higher development in the more sanguineous character of the chyle, in the increased number and more elaborate structure of the vessels and their valves, in the existence of mesenteric glands, and in the concentration or unity of the thoracic duct. The small semilunar folds in the interior of the lacteals are now so numerous and complete, as to check the passage of injections from trunks to capillaries, and to assist in forwarding the chyle to the thoracic duct; and the two membranes forming the parietes of the vessels are now more obvious, and more easily separated. The more simple mesenteric plexuses of inferior classes, now form small condensed conglomerate masses of minute capillary lacteals, interwoven with capillary bloodvessels, so as to form distinct, firm, red-coloured, rounded bodies, enclosed in distinct tunics, and termed conglobate or mesenteric glands, which present a great diversity in their size, their numbers, and their degrees of approximation to each other, in the different orders of quadrupeds. The lacteals and chyliferous glands are almost confined to the small intestine in the inferior vertebrata; but as the colon is more extended in the mammalia, they are now found also, though in smaller proportion, on the mesocolon. The *receptaculum*

chyli is frequently formed, here and in lower classes, by a simple plexus of chyliferous and lymphatic trunks, and that plexus is sometimes extended forwards along the aorta, diminishing the frequency of the anastomoses, to constitute one or two principal thoracic ducts which enter the subclavian veins. Sometimes the branches of the thoracic duct open directly into the *vena azygos*, as in the hog, and a similar communication has been seen as an abnormal structure in man.

The chyle is conveyed so abundantly through the thoraci duct, that six ounces per hour have been computed to flow through that canal in the dog, and on tying the thoracic duct the chyle has been found still to pass forwards to the veins b the enlargement of the lateral lymphatic trunks. There a always distinct valves at the entrance of the thoracic ducts into the veins, to check the return of blood into these dilatable canals, as in all the lower vertebrated classes. The influence of the mesenteric glands on the chyle which passes through their highly vascular and complicated network, is not determined; but, by their grouping and uniting together, they often imitate the lobulated and conglomerate form of other less ambiguous glands. They are of great size in the cetacea, they are more detached in the solidungulous pachyderma and in the ruminantia, and they are often collected into a conglomerate mass, termed *pancreas Asellii*, in the carnivorous quadrupeds. There are forty of these small round lenticular glands in the *bradypus;* they are approximated into a group of about thirty in the hog tribe. In the *myrmecophaga*, those of the small intestine are collected into a mass, and about twenty small glands are spread apart on the mesocolon ; they are also grouped into a mass in the *armadillo*, the *mole*, and the *nasua*. In the *hyrax* they are a little separate, and in the *manis* they are at a distance from each other; but in the rodentia, so inferior in most of their characters, they are the smallest in number and the least developed.

Besides the *pancreas Asellii*, which has always its efferent as well as its inferent ducts, there are generally a few detached mesenteric glands in the carnivora, as in the *otter*, the *seal*, the *badger*, the *dog*, the *cat*, and other species, and the same is seen in the *hedgehog;* but in the *bear* they form two masses, the one belonging to the mesentery, and

the other to the mesocolon. In the quadrumanous animals, as in man, they are spread at a greater distance from each other, and more equally, over the mesentery, and in part over the mesocolon. There are more than a hundred mesenteric glands on the human lacteals, and about a fourth part of these belong to the colon; they are larger and more crowded on the dorsal portion of the mesentery, and more minute and dispersed towards its intestinal margin; but notwithstanding their greater number and development, their uses are not more apparent here than in the simpler forms of vertebrata. The receptaculum is still formed by the union of the lacteal with the inferior lymphatic trunks, the primitive reticulate structure and duplicity of the thoracic duct is still perceptible in the frequent divisions presented in its course, and it still terminates at the junction of the subclavian with the jugular vein, as in most of the vertebrated tribes. And thus the *chyliferous system*, though a mere appendage to the venous, serving to convey nutriment to the blood and performing functions assigned to the veins in the lowest classes of animals, manifests the same laws of formation, and the same plan of perfection in the various grades of its advancement, which we observe in all the more complex parts of the economy, and appears like a remnant of the simpler white-blooded sanguiferous system of the invertebrated tribes still on the march to a more isolated and complete development.

CHAPTER THIRD.

SANGUIFEROUS SYSTEM.

FIRST SECTION.

General observations on the sanguiferous system.

The materials elaborated by the digestive organs and conveyed by the lacteals to the blood, are sent for the nutriment of each point of the body, by a vascular apparatus almost as universal in the animal kingdom as that of digestion itself, and presenting phases of development, in its essential parts, as regular and progressive, as its general form is varied and diversified in the different tribes. As the fountain of all nourishment and of all development is the blood, the peculiarities of this hydraulic apparatus in the different classes, and the laws which regulate its distribution in different animals, and in different parts of the body, involve the chief mystery of their development and form. Half of the animal structure, indeed, is a tissue of minute vessels, and the healthful condition of their fluid contents is alone preserved by the vortex-like movements to which they are constantly subjected by muscular fibres and the nerves, so that the life is in the blood as much as in the heart or the brain. The sanguiferous system being but a radiation of the digestive throughout the body, they keep pace, and follow the same laws, in the march of their development in the animal kingdom as in the embryo. In the embryo, as in the animal kingdom, capillaries precede trunks in the order of formation, as the pulsating vessel precedes and forms the ventricle. The existence of the

ventricle necessitates that of the auricle to perfect its function, and the cleaving of each produces in succession the trilocular and the quadrilocular heart of the cold- and warm-blooded vertebrata.

SECOND SECTION.

Sanguiferous system of the cyclo-neurose or radiated classes.

In the radiated classes of animals, as in the earliest condition of the human embryo, vessels alone are developed to contain and circulate the fluids, without the aid of a heart; and indeed, in the simplest forms, the fluids move in a *cyclosis* through the general cavity of the body, like the colourless blood in the cells of a plant, or the first movements of the globules in the germinal portion of an ovum. This constant slow revolution, forwards and backwards round the interior of the body, is seen in the globules, suspended in a more fluid serum, in the *paramœcium* and other polygastric animalcules, and appears to be produced by vibratile cilia lining the cavity, as all the analogous movements in higher tribes of animals; and the same minute organs are probably the active agents of the currents of globules suspended in a serous fluid, which are seen in the vascular plexuses of the stipulæ and other parts of plants, and around the larger cells which compose their structure. In some of the larger compound polygastrica, as the volvox, a distinct plexus of vessels, forming a reticulate texture, is seen spread over the whole surface of the body, and apparently destined to convey the fluids of the component monads over the general mass of these remarkable aggregate beings. The same active cilia appear to produce the circulatory movements through the ramified and motionless canals of poriphera to nourish and aerate the body, as they obviously effect analogous movements in the bodies of many zoophytes.

The circulation of the blood in many zoophytes was carefully investigated and described by Cavolini fifty years since, especially in *sertulariæ, plumulariæ, campanulariæ, tubulariæ*, and other transparent genera, and his observations have been confirmed and extended by many suc-

ceeding observers. Cavolini observed in the longitudinal cavity of the fleshy axis of their body, a fluid in motion, containing distinct globules like those composing the flesh, which continued during the whole life of the animals, to ascend and descend through all the stems, and the branches and the polypi. These globules, he observed, were contained in a more thin transparent and colourless fluid, not at first very obvious, and he saw them carried upwards and downwards, and sometimes transversely in the cavity of the fleshy axis. The same phenomenon, he perceived, in all the tubular vaginiform keratophytes, the transparency of whose parietes allowed their interior to be examined through the microscope, and, comparing their circulation to that of the larvæ of insects, he designated the fleshy canals through which the blood moves as the heart of these polypipherous animals. The same motions, indeed, in the fleshy axis of the common *sertularia geniculata* had been observed by Lœffling, and described by Pallas before the time of Cavolini. Olivi, who subsequently examined the phenomena of the circulation in *sertulariæ*, considered them as depending on the food and water swallowed by the polypi,which were thus subjected to a peristaltic motion, merely to assist in their digestion. Fleming pointed out a similar circulation in the fleshy axis of the *campanularia gelatinosa.* Chiaje considered the ciliated tentacula of zoophytes as their branchial organs, and supposed that their circulating blood is thus transmitted to them for aeration; he perceived also sanguiferous vessels extending from the base of the polypi in the *coral* and *gorgonia*, and forming a superficial reticulate plexus in the *caryophyllia.* Nordman described a similar circulation of the blood in the *alcyonella diaphana*, which he compared to that seen in the cells of the *chara;* and the motions which I have long since described in the polypi of *flustræ*, *virgulariæ*, *pennatulæ*, and other zoophytes, I have referred to the action of minute vibratile *cilia*—the common agents of all analogous movements in the lowest tribes of animals, and which probably continue to line the serous tubes of the sanguiferous system in all the higher classes, as they are seen vibrating on the serous lining of the cerebral ventricles, even in mammalia, and the most complex form of the sanguiferous system in the animal kingdom is but an extension of the simple cell of a

chara. The colourless chyle derived from the food digested in the stomachs of the polypi, and transmitted in successive portions by the posterior orifice of these digestive sacs, is thus circulated for the nutriment of each part of the system, without the aid of the inert canals through which it moves. In the larger polypi, as *actiniæ*, the vibratile cilia are still more obvious, propelling the currents and globules to and fro through the body and the tubular tentacula of these animals, as the digested fluids were seen by Trembly to pass through the body and the long tentacula of the *hydra*. And even in the *acalepha*, the fluids observed meandering through the motionless canals of their transparent texture, appear to be impelled by the same active agents. The thin serous fluid, replete with globules, continues moving through the longitudinal lateral canals of the *beroe pileus*, while their parietes are seen, through the transparent body of the animal, to remain perfectly motionless, like the sides of the cells of a plant. The same circulation of the nutritive fluids, sent from the stomach, was observed by Eschscholtz in the transparent canals of the *cestum*, and similar currents are seen in the wide canals of the mantle in the *aurelia* (Fig. 113), the *rhizostoma*, and all the larger medusæ, but the minuter filaments, every where distributed through their texture, appear to have no connection with the circulating system. The currents of nutriment thus spread through every part of the system in the lower radiated classes, serve alike to feed and aerate their simple textures, in the same manner as the less isolated currents through the homogeneous texture of poriphera.

A more isolated sanguiferous system however, is seen in the *echinoderma*, where a distinct set of vessels is appropriated to receive the colourless transparent chyle from the alimentary cavity, and to convey it to the respiratory organs, and thence through the rest of the body. These vessels are especially obvious on the mesentery, which so commonly suspends the intestine from the parietes of the abdomen in the animals of this class, as in the *echinus*, *spatangus*, *asterias*, *holothuria*, and allied genera, but no auricle or ventricle is yet developed in their course, although Chiaje has assigned these names to minute sinuses on the ends of the principal vessel of the *sipunculus*. Fluids replete with globules, and

moved by the lining vibratile cilia, are seen advancing and retreating through the transparent tubular feet of these animals, conveyed from vessels and sacs extending along their base. But the capillary veins of the *asterias* arise from the gastric cœca, extend and anastomose along the course of the mesentery, where they are freely aerated, and their united trunks, disposed around the central cavity, give origin to the arteries which traverse and nourish the rest of the body. Into each division of the body, a large intestinal artery passes from the circular trunk around the stomach, and divides into two branches, to be distributed on the two ramified cœca of each. A single arterial trunk is distributed to the feet of each of the rays, and the same number of trunks continue along the whole course of the rays to be distributed on the segments and the superficial parts of the body. The ramifications of these vessels are distinctly seen on the stomach, the gastric cœca, and the ovaries, and in some *asteriæ* a cordeform enlargement is seen on the arterial trunk, which is not developed in other species. In the *echinus*, so closely allied to the asterias in all its organs of relation, the same plan is perceived in the distribution of the vascular system, a circular artery is observed around the mouth, which sends out branches to the long alimentary canal, and five branches proceed to form a vascular ring around the opposite axis of the trunk. A large vein passing forwards along the inner part of the mesentery, enters the circular trunk around the mouth, and the arteries for the tubular feet arise from this oral ring, as in the asterias.

The numerous veins ramified on the intestine and mesentery of the *holothuria* (Fig. 114. *l.*), replenished with chyle from that cavity, unite to form large arterial trunks, which distribute their fluids over the complicated internal branchiæ (114. *h. h.*), extended between the long turns of the intestine (114. *d. d.*) . The arterialised blood collected from the branchial veins is sent forwards and backwards by systemic trunks, the anterior of which forms the usual ring around the œsophagus, while the posterior follows the course of the intestine. The circular trunk around the œsophagus gives off five arterial branches, which supply the apparatus of the mouth, and the general parietes of the trunk, and extending their course backwards, parallel to the long muscular

abdominal bands as far as the cloaca, they give off numerous branches to the superficial parts, and to the tubular ciliated feet, which are here projected from the sides, as in other genera. Other important branches arise from this wide, arterial, œsophageal ring, which pass forwards and backwards to the more deeply seated viscera. The venous intestinal trunks follow the windings of the long alimentary canal, and their branches anastomose most freely with each other on the mesentery of these animals, as in the vertebrated classes. Distinct pulsation is observed in the great arterial trunk and circle around the œsophagus, which gives origin, as usual in this class, to the principal arteries of the body. The blood accumulated in the larger vessels manifests a reddish hue during life, and abounds with globules which unite in a coagulum after death. There appears likewise to be a vascular ring around both extremities of the body in the elongated trunk of the *sipunculus*, and the large connecting median artery, like the dorsal artery of articulata, gives off numerous lateral branches in its course forwards. This artery forms a small sinus at both ends, and gives off the tentacular and other cephalic branches from the œsophageal ring, which it here forms, as in other echinoderma. Regular pulsations have been observed in this long narrow vessel, as in the principal trunk of *holothuria*, and in its terminal enlargements, and the blood has a pale red colour, as in the large arterial trunks of many species of *asterias* and other genera of this class. The same vascular ring, sometimes double or triple, around the œsophagus, formed by the union of the mesenteric and the general systemic veins, observed in most of the larger *asterida*, *echinida* and *holothurida*, is seen even in the smaller forms of *ophiuræ*, where it also radiates arterial trunks to the superficial and the deeply seated parts, and to the vesicles and ampullæ of the feet. The pale red colour so generally perceptible in the blood of the echinoderma, was observed by Cavolini even in that of zoophytes, especially in the longitudinal vessels which occupy the superficial grooves of the axis of *gorgonia*, *corallium*, and other corticiferous forms; and Chiaje observed a yellowish hue in the thin serous fluid, abounding with blood-globules, so extensively circulated through the superficial and the deep seated vessels even of the minutest forms of *acalepha*. There is thus in

the sanguiferous system of the radiated classes, a close analogy not only to the earliest conditions of this system in the vertebrated animals, but also to the permanent conditions of their chyliferous and lymphatic apparatus, especially in the composition and properties of the contained fluid, and in the origin and simple structure of the vessels which convey it, and their free anastomoses with each other. The cyclosis which I have long since pointed out in the bodies of polygastrica, has been more recently mistaken for a revolution of ova, which supposed ova however have never been seen to develope. In the higher forms of these cyclo-neurose animals the afferent vessels may be regarded as *veins* which proceed, whether from the alimentary canal, or the respiratory organs, or from the general system, towards the tubular, pulsating, heart-forming portion of the sanguiferous system; and those efferent vessels may be considered *arteries* which radiate to the system from this central portion, although they appear still destitute of the strong, fibrous, middle coat, developed in the arteries of higher animals, and the veins are still destitute of valves, and similar in structure to the arteries.

THIRD SECTION.

Sanguiferous system of the Diplo-Neurose or Articulated Classes.

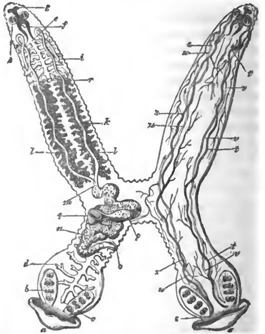
The long cylindrical form of the trunk in articulated animals is observed to impress that form on the sanguiferous system, as well as on the nervous, the digestive, and other important internal apparatus, and is marked especially in the longitudinal direction and the elongated form of the great central arterial and venous trunks. The blood is more highly organized and more deeply coloured, provided with more abundant globules and fibrin, in the articulated than in the radiated animals, and is more remarkable for its deep red colour and its extensive distribution through the body in the soft and slow moving helminthoid classes than in the more active entomoid forms. In most of the articulated classes the blood is observed to move forwards in one or more great

dorsal, pulsating, arterial vessels, the lateral branches of which terminate in corresponding ventral venous trunks, which convey it backwards to the beginning of the dorsal vessel, and it is chiefly in the form and structure of this great muscular pulsating centre that we perceive the higher development of the vascular system in the entomoid than in the helminthoid classes. The internal vibratile cilia are still the principal agents of the circulation and respiration in many of the lower articulata, as in most of the radiated classes, especially where the muscular, pulsating, arterial centre of the sanguiferous system is not yet developed, as in the entozoa and rotifera.

The exterior surface is aerated, and the interior cyclosis is effected, by the same means, in the wide gastric cavities of the *cystic* entozoa, as in the ciliated abdominal sacs of the polygastric and rotiferous animalcules. The limpid serous fluids likewise meander through the inert canals of the *cestoid* and *trematode* worms, without the aid of contractile muscular parietes, as in the similarly ciliated and inert vessels of the acalepha and most other radiated animals; and from the extensively ramified condition of their alimentary canal, the sanguiferous system is less isolated from the digestive than in higher forms. In the *diplostomum clavatum* and *diplostomum volvens*, where the digestive organs are more circumscribed, a distinct system of arteries and veins is perceived to circulate most extensively through the body a thin, red-coloured serous fluid, apparently absorbed from the parietes of the capacious alimentary sacs. A large arterial trunk, giving off numerous lateral branches in its course, is observed, in both these animals, to commence from the posterior extremity of the body, and to advance along the median plain to near the mouth, where it is continued, with diminished calibre, into two great lateral venous trunks. These great lateral veins are directed backwards along the whole extent of the body, and receive numerous branches on each side, many of which are observed to be continuous with the capillaries of the median artery. A single anastomosing canal connects the two venous trunks with each other across the middle of the animal, and connects them likewise with two other longitudinal veins, more central in their position, and extending along the posterior half of the body. In the

annexed view, from Nordmann, of the internal structure of the *diplozoon paradoxum*, (Fig. 132.) which is frequently found attached between the inner laminæ of the gills of the bream, (*cyprinus brama*), the circulation is observed to be conducted in distinct arteries and veins, without the aid of pulsating cavities or vessels, as in other species of this order; and not only is the same plan of the sanguiferous system repeated in the two halves of the animal, but also on the two sides of each half of the body. The two halves of this *trematode* entozoon communicate freely by the digestive canal,

Fig. 132.



and have each a distinct genital apparatus, as we see also in the several segments of the *tænia* and other *cestoid* forms, and dicephalous individuals are occasionally found in the *triænophori* and *cysticerci*, as abnormal forms. At the anterior extremity of each of the long free tapering divisions of the body is seen the transverse crescentic buccal orifice (132. *g*,) of the digestive organs, (132. *e. d. c. r.*) with two lateral suctorial disks, (132. *h*,) and a salivary follicle (132. *f*.); and

together with the ramified cœca of the alimentary canal, the two long convoluted ovaries, (132. *i. k. l,*) the capacious single oviduct, (132. *m. n. o,*) the testicle (132. *p,*) and the spiral *vas deferens* (132. *q,*) occupy the greater portion of each abdominal cavity. The oviducts have distinct openings (132. *o*) at the inner margin, near the proximal end of the two posterior divisions of the animal, like the marginal genital openings of the *tœnia*. The four firm, cartilaginous, oval disks, by which the animal attaches itself to the surface of the gills, are provided each with four suctorial cavities (132. *b. s.*); they occupy the inferior margins of the wide posterior parts of this bifid trunk, and these diverging parts terminate by an expanded fold, with free reverted margins (132. *a. a.*), in form of a valve or protecting mantle. Longitudinal and transverse muscular fibres are obvious within the firm exterior elastic skin, and the light yellow colour of the animal is often changed to red, by the blood, sucked as food, filling the ramified alimentary canal, and appearing distinctly through the transparent texture of the body. The intestine expands like a stomach across the place of junction of the two lateral halves of this animal, but there is no distinct anal opening in the body, and the residue of the digested blood is often seen to be expelled by the buccal orifice, on disturbing the *diplozoon*.

The colourless and limpid serous fluid circulating in the vessels of this animal is carried forwards by two upper, lateral arterial trunks (132. *u. u. v. v.*) in each segment of the body, and it is returned backwards by two corresponding, inferior lateral veins, (132. *s. s. t. t.*), but there is no cordiform dilatation on any part of the sanguiferous system, nor is the slightest pulsation observed in any of the vessels. As in similar minute transparent animals, the ramifications and anastomoses of the arteries and veins, and the currents of the blood are best seen through the microscope by transmitted light, when unobstructed by opaque contents in the ovaries or the alimentary cavities. The two great ventral venous trunks (132. *t. s.*) of each segment are observed to commence small near the sides of the œsophagus, where they soon receive the terminations of numerous peripheral and central veins, collected from the neighbouring parts, especially of two long lateral branches, extending forwards parallel to the

trunks, and two shorter veins proceeding outwards from the internal parts. Reinforced by the accession of numerous smaller branches, the two great venous trunks pursue a winding course backwards, receiving also large branches near the junction of the lateral halves of the body, and they can be traced, converging, as far as the opaque muscular organs of attachment, at the posterior ends of the segments, (132. *a. u,*) where the two arterial trunks commence. The two great arteries (132. *u. v,*) lying more dorsally than the veins, follow a similar tortuous course along the sides of the two segments of the animal, they also are nearly of equal calibre throughout, and their contents are observed to move from behind forwards, while the blood moves backwards in the venous trunks, but neither manifest the slightest systole or diastole. The arteries give off numerous ramifying branches in their whole course, both to the internal and the peripheral parts, those being especially large which proceed to the uterine portion, (132. *m. n.*) of the genital apparatus near the middle of the body, and they become much reduced in bulk, and at length imperceptible, before they reach the sides of the mouth or the commencement of the venous trunks. The minute anastomosing branches of these great lateral arteries and veins form superficial and deep seated plexuses, which are most obvious in the more transparent parts of the body, and especially a compact subcutaneous plexus spread over the general surface; but they here form no median dorsal artery, as in most articulated classes, and there appears to be little vascular connection between the two lateral segments of this animal.

The extensive distribution of the sanguiferous system, the rapid circulation of the blood, and the great superficial plexuses, so conspicuous in the trematode entozoa, buried in the substance of their food, and destitute of anal opening, may enable them to receive or excrete matter through the general surface of their body, as well as through their buccal orifice. This extensive distribution of the circulating vessels has also been especially observed in different species of *distoma* and *amphistoma*, where, from the breadth of the body, the principal trunks are commonly double and lateral, and where they have sometimes appeared to communicate directly with the exterior surface, or with internal sacs, or

with the genital apparatus. The plan of the circulating system is similar in the *polystomum* and *octobothrium*, and from the limpid and homogeneous character of the blood, and the inert condition of the vessels in which it is contained, neither the motion nor the presence of that fluid is perceptible in the transparent canals of the *caryophyllæus*, nor is any motion perceptible in the vessels which convey the blood in the *aspidogaster*. But in the *lernææ*, globules of different sizes abound in the limpid blood, and distinct pulsations are observed in the great central artery of the trunk, as in the higher tribes of articulated animals. In some of the highest entomoid forms, as the *achtheres*, a distinct elongated pulsating cavity is seen extending along the middle of the anterior part of the cephalothorax, which sends two vessels laterally to the prehensile fixed arms, and two similar canals posteriorly to the viscera, thus approaching to the form of the sanguiferous system of the crustacea. By the pulsations of the dorsal vessel the blood is sent rapidly through the canals of the arms and of the abdomen; but in the following instance it appears to return by the same passages, as if they performed the functions both of arteries and veins.

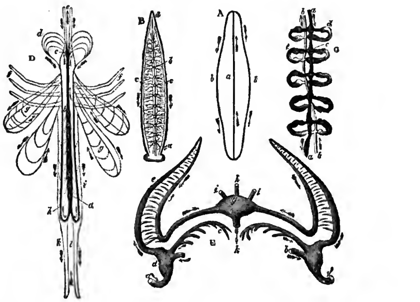
From the transparency and the colourless texture of the body in the *rotiferous* animalcules, vibratile cilia are perceptible on the exterior peritoneal surface, and the interior mucous lining of their alimentary canal, and producing rapid currents of water through the lateral brancheal tubes and tufts disposed along with the extended testes, in the capacious cavity of the abdomen. These more obvious respiratory currents appear to have been mistaken for a circulation of blood, which has not been distinctly perceived to move in the minute sanguiferous vessels of these animals; and the supposed median longitudinal dorsal artery of the *hydatina*, a more careful examination has shown to be a subcutaneous muscular band. In the extended and active state of the body, a circular cervical plexus of minute transparent vessels is perceptible in several genera of rotifera, as *hydatina*, *otoglena*, *diglena*, and *notommata*, and from this anterior vascular network longitudinal vessels appear to communicate with the more symmetrical transverse dorsal arteries of the trunk; but no motion is seen in these vessels, or in their contained fluid. Vessels also appear to pass from these

peripheral parts to form plexuses around the internal nutritive organs, and thence to extend to the internal respiratory apparatus; but many of the supposed vessels of these animals are probably, like the median dorsal, only transparent muscular fasciculi. In the *cirrhopods* the sanguiferous system, like most other parts of their economy, is constructed on the plan of that of the higher articulata, and especially of the crustacea. A wide pulsating dorsal vessel, as observed by Poli, extends forwards along the median line, apparently receiving the blood from the branchial and the inferior systemic veins, and transmitting it by large trunks into the articulated feet and other parts of the body. Simple currents are observed to flow outwards and inwards through the articulated feet, as in insects and the lower crustacea, without ramification of the two bounding canals, and the venous blood appears to return to the fore part of the abdomen, as in crustacea, before being sent to the small branchial laminæ attached to the haunches of the articulated members.

In the *annelides*, as in the larva state of the higher entomoid animals, the blood is extensively circulated through the system by minute arteries and veins; but the great centre of the sanguiferous system is still in an inferior condition of development, presenting only the form of an elongated, simple, pulsating, median, dorsal artery, provided with distinct, circular, muscular fibres, and conveying a thin, red-coloured, serous blood, with comparatively little fibrin or globules, and without distinct cordiform enlargement in its course. The venous blood of these animals is commonly returned from the system to the posterior extremity of the dorsal artery, by a median vein commonly termed vena cava, or by two inferior lateral veins, which collect the blood from the capillaries of the arterial branches, as they pass backwards along the sides of the body. So that the general plan of the circulation in the adult forms of the simpler annelides (represented in Fig. 133. A, where (*a*) is the median dorsal artery conveying the blood forwards, and (*b.b*,) the two returning lateral veins,) not only resembles that of insects and other entomoid animals, but also the earliest embryo condition of this system in the vertebrated classes. This is nearly the course followed by the red blood, observed

through the transparent body, circulating in the arteries and veins of the common brown coloured *erpobdella vulgaris*, (133. B), found creeping on the aquatic plants of our fresh water pools, and guided by eight eyes placed in a curved series along the anterior part of the head, like those of a leech. Here, according to Morren, there are two median vessels, a dorsal and a ventral, (133. B. *a*,) which, by their waves of pulsation, convey the blood into numerous lateral branches, (133. B. *b*,) the capillaries of which are continuous

FIG. 133.



with those of the two great returning veins, (132. B. *c. c*,) extending backwards along the sides of the body; the inferior median vessel, however, is probably a returning vein. In the *prostoma* and various other broad forms of *planariæ*, the thin, red coloured serous blood is also observed to be conveyed forwards by the contractions of a single median dorsal artery, and backwards by two lateral inferior venous trunks, which present two small vesicular enlargements in their course, analogous to the more numerous minute sinuses seen on the vascular trunks in the *lumbricus* and many other annelides. The *planaria viganensis* has two minute sinuses on the anterior part of each of

the lateral vessels ; and posteriorly these vessels send each a large branch to the ovary and cloaca. In the *nais*, the usual median dorsal artery, propelling the blood forwards, divides at the anterior part of the neck, and descending on each side of the œsaphagus, forms, as in many other elongated narrow species, a single inferior median epi-neural vein, by which the blood is conveyed posteriorly. This arterial œsophageal ring of the *nais* exhibits the same regular systole and diastole, which are seen in the dorsal artery, and which are obvious in the corresponding sacculated arterial rings passing down from the anterior part of the great dorsal artery to the ventral vein of the *earth-worm*, (133. C. *c*, *d*.) Where there are two median trunks, a dorsal and a ventral, in the sanguiferous system of the annelides the inferior is commonly a smaller returning vessel, extending along the motor surface of the nervous columns, as in the entomoid classes, and analogous to the descending abdominal aorta of fishes, and the embryos of higher vertebrata. So that the position of the heart-forming dorsal trunk, the median ventral vessel, and the vascular rings or branchial arches which connect them, in many of the articulated classes, correspond precisely with the inverted position which I have shown in their moto-sensitive nervous columns, and other important organs.

The simplest condition of the circulating system is seen in those which have no perceptible respiratory organs, as in the *nais* and *planaria;* but considerable modifications of the general plan are induced in higher genera, by the development of organs for this function, in form of internal air sacs, or of external cephalic or dorsal branchiæ. The high cutaneous vascularity appears to supply their place in the abranchiate species, where the ramifications of the blood vessels are quite distinct from those of the digestive apparatus. The long dorsal artery of the *nereis cuprea* appears to be slightly dilated in each segment of the body, and receives or gives off the branchial vessels from the arterial arches which encompass the œsophagus; but in other species the branchial vessels are given off to these organs from each side of the dorsal vessel in its whole course forwards, and small pulsating vesicles are generally perceptible on the lateral systemic branches of the aorta. The little tubicolous *clymene* likewise gives off from the great dorsal artery conveying red blood, numerous lateral branches extending like branchial

arteries to the lateral pairs of feet. In the cephalo-branchiate marine *serpulæ* and *sabellæ*, the arterialised blood is returned by the branchial veins to two elongated sinuses placed at the sides of the œsophagus, the aorta and vena cava occupy the median plain, giving off symmetrical lateral branches, and the dorsal vessel appears slightly enlarged in each segment. The branchial veins of the *amphitrite* likewise convey the arterialised blood to two vesicular sinuses which unite below the œsophagus, and from these branchial sinuses in the *terebellæ* the two lateral systemic veins take their principal origin.

From the deep red colour of the blood, and the colourless transparency of the general tissues of the body, in the common *pectinaria* of our sandy coasts, the pulsations of the wide dorsal artery are easily observed, extending in successive waves from behind forwards, and also the numerous branches sent off laterally, which reduce the calibre of this great artery at its anterior part. Besides the usual median dorsal artery, and the median ventral trunk above the nervous columns, in the *pleione carunculata*, there are two lateral dorsal vessels which communicate freely, by anastomosing branches, with the median dorsal artery, and also two lateral longitudinal ventral veins, which send numerous branches to the branchiæ. The arterialised blood appears to be collected from the branchiæ by the lateral dorsal vessels, and to be transmitted partly by their internal anastomosing branches, into the median dorsal artery, and partly by their own branches to the principal organs of the body. The venous blood of the system is collected from the superficial parts and the internal viscera into the great lateral veins, and is thence transmitted through the minute laminæ of the external branchiæ, before it is received by lateral arterial trunks for the nourishment of the system. The highly sensitive and muscular pharynx is provided with a large and distinct plexus of vessels, connected, like the numerous plexuses of the alimentary canal, with the great inferior lateral veins, which give origin to the branchial arteries. The median dorsal artery is here chiefly connected with the alimentary canal, as the median ventral vein is, in this and most other articulated animals, connected with the nervous columns. From the equal development of the great vascular centres throughout the body of the annelides, and the nume-

rous anastomoses among the principle sanguiferous trunks, it is easy to perceive how the circulation in these animals can, by the closing of the divided ends of the vessels, become accommodated to extensive mutilations, and proceed without interruption in a few segments detached from the trunk. Some of the simpler forms, as *stylaria*, are thus enabled to extend their means of propagation by the spontaneous transverse division of their body.

Besides the ordinary dorsal artery, extending forwards between the fifteen pairs of ramosc branchiæ in the *arenicola*, the great subgastric vein, and two smaller vessels extending along the sides of the nervous columns, distinct longitudinal gastric vessels, one superior and one inferior, are seen extending along the alimentary canal, and forming delicate plexuses on its parietes. The numerous branchial vessels are observed to be connected directly with the great dorsal and ventral trunks. As in most other annelides, enlargements, here one on each side, are formed at the anterior part of the body, on the anastomosing branches between the great superior and inferior median vessels, and these two sinuses have bcen considered as the two auricles of the heart in this animal—cavities, however, which are not found co-existent in the heart of animals lower than the amphibious vertebrata. The arterialised blood from the ramified branchiæ of the *amphinome* appears to be collectcd, as usual, into two longitudinal lateral trunks, which convey it, by numerous anastomoses, into the great advancing trunk of the dorsal vessel, before that systemic artery turns downwards and backwards, to ramify on the internal viscera; and it is again collected from the system into venous trunks, from which the branchial arteries convey it to the respiratory organs. The same plan of the circulating system is seen in the *leech*, where the great median dorsal and median ventral trunks are extended along the whole body, giving off numerous symmetrical branches on each side in their course; and two large lateral vessels follow along the margins of the segments, receiving in their progress regular alternating branches from the superior and inferior parts of the body. The great ventral vein extended beneath the alimentary canal, appears to be enlarged opposite to each of the subjacent ganglia, and to encompass the nervous columns by its numerous circles of anastomosing branches, producing thus a hypo-neural as well as an epi-neural vein;

its lateral branches also form regular vesicular enlargements near the sides of the nervous ganglia. The lateral vessels are wider than the median, their branches anastomose with each other, and also with the dorsal vessel, and they appear to receive the aerated blood from the respiratory vesicles, as the lateral vessels receive it from the branchiæ, in other annelides. Their tapering ends are united by anastomosis across the median plain, both anteriorly and posteriorly, so that they form a continuous canal around the margin of the body; and their large dorsal branches, at the posterior portion of the body, form five long rectangular meshes by their free junction across the segments. The dorsal vessel commences posteriorly by two branches, which unite together at the pyloric end of the stomach, and all the vascular trunks of this animal give off or receive their branches with a symmetry equal to that of the nervous system.

The blood is also of a deep red colour, and charged with globules, in the earth-worm, *lumbricus terrestris* (Fig. 133. C.), and from the greater transparency of the body, the direction of the internal currents is more perceptible than in the more opaque body of the leech, where it is necessary to examine this part in very young individuals, and where the currents have appeared often to change their direction through the vascular trunks. Successive waves of contraction are distinctly seen in the earth-worm, extending from behind forwards along the wide dorsal vessel; and by removing the integuments and pressing this artery between the forceps, it becomes empty in front and turgid behind. It appears to receive the arterialised blood from the air vesicles, and sends off numerous lateral branches in its course, especially to the alimentary canal and the genital organs. The venous blood is collected from the viscera chiefly by the great median subgastric or epi-neural vein extending backwards between the digestive canal and the nervous columns; and this vessel appears to send off branches to the numerous minute respiratory vesicles. A small inferior median vessel or hyponeural vein is also perceived extending along the under surface of the nervous chords, and an accompanying lateral branch is seen as usual on both sides of the same columns. Anterior to the commencement of the stomach, the great dorsal artery, (133. C. *b. b.*) communicates with the median subgastric vein, (133. C. *a. a.*) by five or more pairs of lateral

wide, sacculated arches, (133. C. *c. d*,) which embrace the œsophagus, as the corresponding vascular arches which connect these two vessels in other annelides and in the entomoid classes. Some branches of the pulmonary arteries which arise from the sides of the sub-gastric vein, are observed to terminate in minute sanguineous vesicles, as in the leech and other annelides, and this vein presents slight enlargements opposite to each ganglion in its course, as in many other species of this class. So that the pale red colour of the blood, the want of a muscular cordiform cavity, the imperfect development of valves, the frequent free anastomoses of the great vascular trunks, and the numerous small pulsating vesicles, seen on the sanguiferous system of the annelides, are conditions in which it resembles also the lymphatic system of the lowest vertebrated classes.

The uniformity of the general plan of the circulating system is still more obvious and more constant in the entomoid than in the helminthoid classes; and this is especially manifest in the position and function of the great median dorsal vessel, the median sub-gastric vein, the œsophageal arches which connect these two great vascular trunks, and the lateral vessels most connected with respiration. The least deviation from the ordinary form of the sanguiferous system of the annelides is found in the *myriapods*, the most vermiform of all the entomoida; and it is only in the highest forms of crustacea that we first arrive at the development of a strong, muscular, capacious ventricle on the great systemic, arterial trunk. The great dorsal vessel in the myriapods is still in form of a narrow, sacculated, pulsating tube, extended along the middle of the whole trunk of the body. In the *scolopendra* this dorsal muscular vessel or heart begins from the last or caudal segment, and is continued forwards, segmented in appearance, but with little change of calibre, to the second segment behind the head, where it becomes smaller, and is prolonged in the same median line to near the mouth. At the commencement of this narrow anterior portion or aorta, two lateral trunks are given off, to form the usual œsophageal anastomosing arches between the dorsal artery and the median sub-gastric vein. The long narrow dorsal vessel of the myriapods is retained in its situation by the same lateral muscular bands which suspend the heart from the dorsal part of the segments in the other entomoid

classes. A second pair of vessels originate from the sides of the prolonged arterial median trunk in the head, and a third smaller pair are given off from the same vessel, as shown by Straus and Meckel, near the mouth, which supply the neighbouring parts. The œsophageal ring, which also sends forwards small branches, is formed as usual by lateral branches extending from the anterior part of the aorta to the median subgastric or epi-neural vein; and this vein continues backwards, as in other articulata, along the upper surface of the nervous columns to the posterior extremity of the body. This small soft, pellucid vein, lying loosely on the motor columns which I have above described, and from which it is easily lifted, appears to have been mistaken here, as also in the arachnida, for a nervous filament imagined to have some connection with the sympathetic system, or with the function of respiration. It is extensively connected by branches with the peripheral musculo-cutaneous parts, with the large, tortuous, ramose tracheæ, and with the reticulate peritoneal covering of the alimentary canal, but has no resemblance to a nervous filament, in form, texture, or mode of distribution. The elongated and simple form of the heart in the myriapods, and the whole condition of their circulating system appear thus, like the other organs of their body, to be more closely allied to those of the inferior annelides, and of the larvæ of insects, than to the highest adult forms of the latter animals, as supposed by Meckel.

The sanguiferous system of *insects*, like their nervous system, and most other parts of their economy, not only undergoes important changes during the growth and metamorphoses of these animals, but also presents various forms and conditions of development in the adult state of the different orders of this class. From the opacity of the integuments in adult insects, and the limited distribution of blood vessels through their highly aërated body, the course and extent of their circulating system were long concealed from observers, and the dorsal vessel was early believed to be a glandular sac shut at both ends, and destined, by its continued peristaltic action on a contained honey-like substance, to form the abundant fatty matter of their body. By examining, however, minute transparent larvæ under the micros-

cope, and the soft parts of perfect insects, newly escaped from their larva covering, it was distinctly seen by several accurate observers, as Leuwenhock, Nitzch, and Baker, that there is a motion of blood, containing globules, in different parts of the living body of these winged articulata. It was especially observed by Baker, that in certain larvæ a motion of blood globules is obvious, extending forward along the middle of the back, and returning backwards along the sides of the body—thus completing the circulation. The anterior divisions of the dorsal vessel being concealed by the opacity of the head, it was for some time supposed that that vessel propelled its contents, by an open anterior orifice, into the general cavity of the trunk, and that the fluid, by being re-admitted into the posterior part of the dorsal vessel, thus performed a circular motion. The sacculated structure of the dorsal vessel, (Fig. 133. D. *a. b,*) or heart of insects, had already been observed by Swammerdam and Lyonet, and even by Malpighi; but the valvular arrangements and the lateral openings of its eight compartments, were first minutely examined by Straus.

In the larva state, as in the simpler annelides, the dorsal vessel has a more lengthened, narrow, thin, and uniform appearance, than in insects which have arrived at their chrysalis or at their imago state; and we observe this vessel to thicken its parietes, to shorten its extent, and to perfect its internal valves, as the muscles of the segments, during the metamorphosis, contract and imbricate the consolidating integuments, and thus shorten the whole trunk of the body. The eight chambers of the heart appear, like the segments of the abdomen, to be inserted into each other from behind, and the bilabiate valves, with their free edges directed forwards, are formed by a reflection inwards of the tough inner parietes of this vessel, and as they are confined to the posterior or abdominal portion of the heart or aortal trunk, there appears to be a pulsating muscular sac for each segment. These cavities contract in succession from behind forwards, and convey a thin, colourless serous fluid, abounding with large blood globules; they receive this blood posteriorly from the abdominal veins, and each cavity (133. D. *a. b.*) likewise receives two lateral currents poured into its posterior end from the cavity of the

abdomen. The heart, still destitute of auricle, is attached, as in other entomoid classes, to the upper and lateral parts of the segments, by muscular bands extending from the sides of each cavity; these muscular bands have a triangular form, tapering as they proceed laterally to the segments, and they leave narrow openings between their broad insertions into the tendinous, investing pericardium, to admit the lateral abdominal currents. From this median dorsal abdominal heart, the thoracic aorta is continued forwards, with thin membranous parietes, and without sending off branches, to the head where it has been shown by Carus to divide into several lateral currents (133 D. *c. d.*), but the parietes of the aorta are not perceptibly continued onwards around these currents so as to confine them within distinct vascular canals. The current of blood-globules from the anterior part of the aorta is observed to divide into numerous distinct arches (133 D. *c. d.*) which radiate upwards, laterally and backwards, sending off similar isolated currents to the antennæ and other parts of the head, but there is no appearance of vascular ramifications or capillary vessels in the sanguiferous system of insects, which we observe so remarkably developed on their respiratory organs, and which are obvious in the circulating vessels even of the lower annelides.

The currents of blood, forming arches or loops in the head and its appendices, reunite and terminate in the two great lateral inferior returning veins which, in their course backwards, give off similar small currents to the legs and the wings. A single stream is observed to enter the anterior part of the haunch in each of the legs, (133. D. *f. f.*) and to flow, on the same side, towards the tarsi, but to a variable distance in different insects; the current returns on the opposite part of the leg, to the haunch, and re-enters the great abdominal vein of that side, so that a single loop sometimes reaching to the tarsus, is thus formed by the current in each leg. The blood, however, is more extensively distributed over the wings, especially in the soft and pliant condition of these parts, when first escaped from the larva covering or the chrysalis state. Although the course which the blood follows in traversing the wings of insects, is very different in different species, and varies according to the form, structure, and reticulations of these organs, it is

observed in all their forms, to pass by one or more wide vessels, outwards from the ventral veins, along the thick anterior or upper margin, and to return to the same great venous currents, along the thin posterior edge of the wings, as represented in the four dissimilar wings placed in the annexed diagram (133. D. *g. g.*) In the first soft rudimentary state of the wing in the larva, the excurrent and recurrent streams form a single undivided loop around the margin, as in the shooting branchial laminæ of the tadpoles of amphibia, and the wings of adult insects have been compared indeed to dried branchiæ.

In the mature wings, the wide alar bloodvessels describe various forms of curves, loops, and meshes, peculiar to each species, and accompanying and perforated by the ramifications of the alar tracheæ; but these currents, which are rendered visible only by the moving large ovoidal blood-globules conveyed in the colourless serum, become gradually obliterated, and restricted to the larger vessels, as the wings dry and harden by use, as the respiration is increased over the system by the extension of the tracheal ramifications, and as the necessity for nutrition and development diminish over the system. There are sometimes hundreds of blood-canals meandering through a single membranous wing, and most of these canals embrace each one or more tracheal branches which follow along their interior, and which appear to oxygenate, while they are surrounded by, the circulating blood. The circulating system of insects is thus perforated and permeated by the respiratory, as the alimentary canal of many mollusca is permeated by the great trunks of the sanguiferous system. There are more excurrent than recurrent streams along the margins of the wings; the vascular parietes which bound these wide currents are not perceptible; and the number or size of the accompanying atrcheæ are not proportioned to the width of the blood-canals, which embrace them. There are of course no valves in these alar canals, and the blood is observed, on the slightest interruption to its free course, to stop, or retrograde, or ocillate backwards and forwards in the same vessels, and by the constant anastomoses of these canals a reticulate structure is produced, like that of the adult capillaries and the first formed embryo-vessels in the highest vertebrata.

The united recurrent or venous trunks extending along the posterior margin of the wings return to the great lateral abdominal veins, which convey the blood backwards to the posterior end of the dorsal vessel. Several currents, apparently continued from the abdominal veins, are also perceived moving to and from the principal viscera of the trunk, and exterior to these great returning abdominal currents, two smaller veins (133. D. *h. i.*) are seen extending laterally nearer to the openings of the stigmata. These smaller accessory abdominal veins receive the blood from the neighbouring exterior parts, and convey it by several short canals to the great returning veins. Abdominal currents are also sometimes perceptible, directed to the principal viscera, especially to the genital organs and to the biliary tubuli. As the aortal arches of the head are observed to give off small currents to the various appendices of its united segments, and the great returning veins to send similar currents to the locomotive appendices of the thorax, so we observe the caudal (133. D. *k. l.*) and other appendices of the abdomen to receive small streams of blood-globules from the great ventral veins before they open into the posterior segment of the heart. The prime mover of the circulation in insects is obviously the muscular structure of the heart, and the direction is given by the numerous semilunar valves of its compartments. From the free aeration of the circulating fluid by the tracheæ in every part of the body, there is as little difference between the contents of arteries and veins, as in the structure of these canals which perform the same functions in all parts of the body, and hence the high temperature and the rapid evolution of caloric, shown by Berthold, in the body of these most active of the invertebrata. The diminished extent of the circulation in the imago state or last stage of insects, when the organization is completed, and the end of their career approaches, better fits these light aeronauts to flit through the attenuated air, and corresponds with the senile condition of this system in higher classes of animals.

The heart of the *arachnida* is generally suspended, like that of insects, by means of transverse muscular bands, from the dorsal parts of the segments, but that of the phalangium appears to extend free along the middle of the back. In the short abdomen of the spiders, the heart is also short, wide,

sacculated, and provided with a distinct muscular coat consisting of strong circular fibres. It is attached by transverse muscular bands, it terminates suddenly at its anterior part in a narrow membranous aorta, and it gives off numerous lateral ramifying arteries from its saccular enlargements; it originates posteriorly from the union of several large returning venous trunks; several of its branches are observed to ramify minutely through the granular fatty substance of the abdomen, and others are derived from the pulmonary sacs. From the anterior part of the aorta, as shown by Treviranus, two large lateral trunks diverge on each side, and the diminished median artery continues forwards to the head as in the myriapods; he has likewise observed two lateral venous canals extending along the abdomen. I have found four compartments of the heart in spiders as in the common *tegenaria*, which are each provided with distinct valves, and with lateral narrow depressions or openings, as in the heart of the scorpion and in that of insects. The first or posterior chamber is very small and narrow, situate nearly above the anus, provided with opaque muscular parietes, and receives the thin membranous trunks of numerous minutely ramified veins. The second compartment is much larger and longer than the first, the third is the longest and the broadest division of the heart; and the fourth or anterior compartment, which is situate immediately behind the junction of the abdomen with the cephalo-thorax, is as short as the first, but the most thick and muscular in its parietes. These divisions of the heart give off lateral branches; they are dilated at their line of junction where the valves are placed, and the narrow lateral slits which have a dorsal aspect; and they extend along the dorsal part of the abdomen, immediately beneath the integuments, from the anus to the cephalo-thorax where the short thin membranous aorta commences.

The heart of the *scorpion* is, on the contrary, confined to the anterior part of the body, or alvithorax, and consists of a greater number of compartments than in the spiders, amounting here to six or eight distinct cavities. These cavities are furnished with lateral suspensory muscular bands, and strong muscular opaque parietes, composed chiefly of transverse fibres; they are dilated at their

extremities, and provided with terminal valves; they present narrow lateral openings at their dilated extremities, and they give off symmetrical branches on each side. They constitute a wide fusiform sac tapering much at its extremities, and extended along the middle of the back from the proximal caudal segment to the third pair of legs; they are connected with the internal organs by lateral vessels, especially with the hepatic tubuli, the fatty substance, and the pulmonary sacs; and the internal terminal valves produce an articulated appearance of the heart externally, as observed by Treviranus. As in other entomoid animals, the anterior part of the thick muscular opaque heart terminates suddenly in the thin membranous transparent aorta which appears to widen before dividing into lateral branches, and the small posterior compartment of the heart receives the great median dorsal vessel of the caudal segments. The anterior distribution and lateral arches of the aorta nearly resemble those of the scolopendra, and the blood appears to be returned backwards chiefly by the epineural vein, accompanying the moto-sensitive columns, as commonly seen in myriapoda, crustacea, and other articulated animals.

The higher *crustaceous animals* exhibit a more perfect development of the sanguiferous system, in the structure of the heart, the fibrinous character of the blood, and the extent of the arterial and venous distribution, than is presented by any other of the articulated classes; but in the lower forms of these animals, as in isopoda and stomapoda, the circulation more resembles that of annelides and the larvæ of insects, especially in the elongated and simple form of the dorsal vessel, and the absence of capillary ramifications. From the defined nature of the respiratory organs of crustacea, and the imperfect aeration afforded by the medium in which they live, the double circulation of these animals, like that of the pulmonated arachnida, is more complete than in other articulata, and the heart is systemic as in almost all the invertebrated tribes. The venous blood in the decapods, as in the *maja squinado*, (Fig. 133. E.) is collected from the various members by distinct brachial veins, (E. *a. a.*) and from the upper and lower parts of the trunk by a series of superior (E. *c.*) and inferior (E. *b.*) abdominal veins, which convey it to capacious lateral sinuses connected freely with each other, and situate at the bases of the several branchiæ. The bran-

chial arteries, (E. *e. e.*) originating from these wide membranous sinuses on each side, distribute the whole venous blood of the system over the innumerable minute laminæ of the gills, and from these it is collected by the branchial veins, (133. E. *f. f.*) to be transmitted to the heart. The branchial arteries follow the outer margin, and the returning veins the inner margin of the gills, and the united trunks of the latter vessels convey the arterialised blood, by a single orifice on each side, into the large median muscular ventricle. (133. E. *g.*)

The heart, as in other articulata, is situate in the middle of the back, as seen in the lobster, (Fig. 119. A. *e.* B. *g.*) and consists of a single systemic muscular cavity, most concentrated in form in the decapods, and generally elongated like a dorsal vessel on the inferior orders; its thick parietes are composed of interlaced muscular fibres, they present internal fleshy columns, there are semilunar valves at the orifices of the great vessels, and the heart is connected, as usual, with the neighbouring parts by muscular bands. From the anterior and upper margin of the heart arise three arterial trunks, (133. E. *i. i. h.* 119. B. *h. h. i.*) the two lateral of which send branches to the genital organs and the stomach, and terminate in the two antennal arteries proceeding to the outer and inner pair of these organs, and the median vessel, (119. B. *d.*) advancing over the stomach to the pedunculated eyes, divides into the two ophthalmic arteries which supply these organs. From the lower and anterior part of the heart, the hepatic arteries (119. A. *g.*) originate by a single or double trunk according to the divided condition of the liver through which they ramify; and from the lower and posterior part of the same muscular cavity arises the great sternal artery (119. A. *k.*) which, after descending to the sternum and dividing into an anterior, (119. A. *l.*) and a posterior (119. A. *m.*) trunk, supplies most of the musculo-cutaneous parts on the ventral region of the body, and gives off laterally the brachial arteries to the locomotive organs. From the middle of the posterior margin of the heart is given off the great posterior median systemic artery, (119. A. *h.* B. *k.* 133. E. *k.*) which, extending backwards along the median and dorsal part of the trunk, sends off numerous branches on each side to the neighbouring organs, and bifurcates over the colon before distributing its terminal branches on the muscles of the tail (119. A. *i.* B *f.*)

The venous blood of the system is returned to the great ventral and branchial sinuses and transmitted through the gills, and when arterialized is conveyed upwards to the dorsal part of the trunk by the branchial veins, to be poured into the cavity of the heart by two orifices on its upper surface (119. B.) The venous and the arterial openings of the heart are provided with valves; this organ is already furnished, as in mollusca, with a delicate pericardium which has often been mistaken for an auricle, and there appear to be numerous venous sinuses developed on the superficial parts of the trunk, besides those connected with the branchial arteries. There is thus only a single cavity of the heart developed, from the gradual concentration of the extended dorsal vessel, in the highest of the articulated tribes, which accords with the general muscular activity of this sub-kingdom, and this single ventricle is systemic as in other invertebrata and in the embryos of the vertebrated classes. And in tracing the successive phases of the development of this muscular cavity in the highest decapods, it is observed to pass through the adult conditions presented by the inferior orders of crustacea, and by all the lower articulated classes.

FOURTH SECTION.

Sanguiferous System of the Cyclo-gangliated or Molluscous Classes.

The existence of a muscular ventricle on the great vascular trunks of the system, by interrupting the equable current of the blood, necessitates the development of an auricle to relieve the veins from regurgitation and distention, and to perfect its own function; and as these two cavities are not synchronous in their development, we observe a higher grade of the sanguiferous system in the existence of an auricle, superadded to the ventricle, throughout all the classes of mollusca. These two cavities are systemic, as the heart in other invertebrata, and this high condition of the vascular system accords with the complicated structure of the digestive, the glandular, and other nutritive organs of these animals. As the respiration of the mollusca is almost always aquatic and limited, their muscular energy and movements are languid, and the

systemic position of their heart is thus necessary to accelerate the circulation and nutriment of their inert frame. The auricle is often divided, and sometimes also the ventricle, in the mollusca, as we find the kidney, the spleen, the liver, and many other organs, divided into parts in their lowest or their earliest forms, but the functions of the parts are always the same, and this divided condition of the cavities is often necessary from the lateral position or the distance of the branchiæ, or to suit the general form of the body. Although abounding in fibrin and globules, and affording a white coagulum after death, the blood of the living mollusca is still thin, transparent, and colourless, or of a pale bluish-white hue, rarely red coloured, but the parietes of the vessels which convey it are now always distinct and their three tunics are commonly perceptible, as in the vertebrated classes. The diversities presented by the circulating organs are greater than in the articulated or the vertebrated tribes, and depend chiefly on the remarkable differences of form found in molluscous animals, on the difference of position and character of their respiratory organs, and on the various grades of development presented by their general organization.

The heart of the *cynthia*, and many other isolated forms of *tunicated animals* is situated, as in the conchifera, in the abdominal cavity, between the alimentary canal and the muscular enveloping mantle; it is contained in a distinct pericardium, and consists of a dilated muscular portion of the great systemic artery, which was observed by Dicquemare to pulsate in the living animal. This muscular pulsating and transparent heart, consists of an elongated fusiform ventricle, with a minute auricular dilatation observed by Chiaje to be partially divided, as in the inhabitants of bivalve shells, and to possess distinct valves at their venous orifices; and these cordiform cavities are so situate as to receive the arterialised blood from the reticulate laminæ of the gills, by two branchial veins, into the bifid auricle, and thence into the ventricle to be propelled through the single systemic aorta. The auriculo-ventricular orifice is already provided with distinct valves, and the systemic aorta extends along the dorsal part of the abdominal cavity towards the anus, between the alimentary canal and the mantle, and following along the course of the intestine. Both the auricular and the ventri-

cular valves were shown by Chiaje to be already sufficiently developed in *ascidiæ* to check the flow of mercury when injected in a direction contrary to that of the natural current of the blood. The venous blood of the system and the nutriment absorbed from the wide and highly vascular intestine appear to be transmitted by venous trunks to the branchial arteries and the gills before they are conveyed to the heart; and the same plan of structure is more or less perceptible in the different forms of simple and compound tunicata; as shown by Savigny, Chiaje, Cuvier, Schalck, Meckel, and other anatomists, although their descriptions do not always coincide.

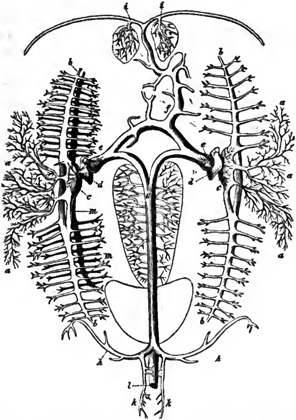
The different parts of the heart and of the whole vascular system are more distinct and more complicated in the *conchiferous animals*, than in the tunicata, but they are constructed according to the same type in these two classes of acephalous mollusca, which consist entirely of aquatic and branchiated animals. The heart is always systemic, and is placed as in the former class in the dorsal part of the abdomen. It consists of an auricle, commonly divided into two lateral parts, which receives the aerated blood from the gills, and of a ventricle, also sometimes divided into two lateral parts, which transmits the blood to the aorta and systemic vessels. The blood is colourless or of a bluish-white colour, and rarely of a reddish hue. The venous blood is collected from the system by venous trunks, and transmitted directly to the branchial arteries to be spread over the large free pendent reticulate and pectinated folds of the gills. From the lateral position and the symmetrical development of the branchiæ and of the margins of the mantle, the palleal veins (Fig. 134. *a. a.*) returning from the ciliated and aerated covering of the thoracic cavity, and the branchial veins (134. *b. b.*) returning the aerated blood from the gills, are separated to a distance from each other on the two sides of the body. The two sinuses which receive this aerated blood, and which constitute the auricle (134. *c. c.*) of the heart, are therefore placed apart from each other, and form two distinct cavities, in almost all the conchifera. Their form is somewhat triangular, with their largest side towards the branchial veins, and their largest angle towards the ventricle, and their parietes, though thin, present distinct muscular fasciculi. They have several openings for the branchial and the palleal veins,

and they communicate by a single valved orifice with the thick-walled muscular cavity of the ventricle. In the oyster (120. A.) where the body is much compressed and very narrow transversely, the two parts of the auricle (120. A. *f.*) are united together on the median plain and constitute a single cavity, communicating however, by two distinct orifices with the ventricle (120. A, *g*). The auricle and ventricle are inclosed in a capacious pericardial cavity, which is situated, in the oyster, in the concavity of the great adductor muscle, (120. A. *l.*) The ventricle is generally single and placed in the middle of the back, as seen in the *spondylus* (120. B. *i.*) receiving on both sides, from the divisions of the auricle, (120. B. *h.*) the arterialised blood transmitted by the palleal, (120. B. *f.*) and the branchial (120. B. *g.*) veins. As the rectal portion of the intestine (120. B. *i. e.*) occupies the median line of the back, it commonly perforates the ventricle in its course to the anus, and thus indicates a partial internal division of this muscular cavity. In some, as the *teredo*, the ventricle is cleft posteriorly into two parts, but communicates by a single opening anteriorly with the aorta; and in the *arca noæ*, (Fig. 134) the ventricle is entirely divided into two distinct and separate parts, (134. *d. d.*) each of which communicates by a distinct *bulbus arteriosus* (134. *e. e.*) with the great trunk of the anterior (134. *f.*) and posterior (134. *g.*) *aortæ*. The auriculo-ventricular and aortal orifices of the ventricle are furnished with semilunar valves which prevent the return of the blood, and the bulbus arteriosus is most apparent at the origin of the aorta where, as in the *arca noæ* and the *ostrea*, the ventricle is not perforated by the intestine. The ventricle, as shown by Cuvier, is divided into two separate parts, also in the *lingula*, among the brachiopodous conchifera, and both the anterior and posterior aortæ, as well as the ventricle, are frequently traversed by the intestine in the bivalved mollusca.

When the ventricle is median and perforated by the intestine, it is commonly elongated and fusiform, and tapers anteriorly and posteriorly into the commencements of the corresponding aortæ. The anterior aorta is mostly a visceral artery, supplying the stomach, the liver, the ovaria, and other abdominal organs, and the posterior aorta has generally a musculo-cutaneous or a palleal distribution. In

those which, like the *arca noæ*, have the ventricle and the bulbus anteriosus double as well as the auricle, the

FIG. 134.



anterior and posterior aortæ have necessarily also a double origin. From the bulbus arteriosus (134. *e. e.*) of each side arises a large single arterial trunk, which immediately divides into the usual anterior and posterior aortæ (134. *f. g.*) The two divisions of the anterior aorta, thus formed, anastomose into a single median trunk (134. *f.*) which advances forwards to near the mouth, sending off numerous large arteries to the ovary, the liver, the stomach, and other viscera of the abdomen in its course. Arrived at the anterior part of the body, this median trunk, greatly diminished in size, bifurcates to form the anterior palleal

arteries, which extend backwards ramifying along the anterior edge of the mantle, and give off branches to the anterior adductor muscle, (134. *i. i.*) and to the sensitive and vascular apparatus around the mouth. The distribution of the anterior aorta is nearly the same where it arises by a single trunk from a single median ventricle, as here where it has a double origin, and the same observation applies to the general distribution of the posterior aorta, even when it originates as a mere branch from the anterior or single systemic aorta, as in the *oyster*.

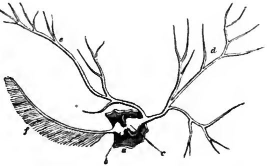
The posterior aorta most frequently arises by a single trunk from the posterior or anal extremity of a lengthened median fusiform ventricle, and continues backwards along the median plain, above the intestine, to near the anus or the vent, where it bifurcates to form the two great posterior palleal arteries, which follow the course of the posterior and inferior margins of the mantle. In the bicordate forms of this class, as the arca noæ, the posterior, like the anterior aorta, commences by a double origin from the right and left bulbus arteriosus, (134. *e. e.*), and the two trunks soon anastomose to form the usual median posterior dorsal artery (134. *g.*) In its course towards the anus along the middle of the back, the posterior aorta gives off numerous small lateral branches, (134. *g.*) like intercostals, which spread chiefly on the muscular parts of this portion of the abdomen, and proceeding, with the colon, over the great posterior adductor muscle, which it also supplies, it divides above the anus (134. *l.*) into the right and left posterior palleal arteries (134. *h. h.*) Near to their origin, the posterior palleal arteries give off each an anal branch, (134. *k. k.*) which two branches encompass and supply the rectum and continue their course, ramifying along the curvature of the posterior adductor muscle. The great palleal trunks (134. *h. h.*) extend along the posterior and inferior margins of the mantle, sending off numerous branches to its appendices, and ramifying extensively over that expanded and ciliated covering of the respiratory cavity. From the capillaries of this almost respiratory membrane, the blood is collected by the palleal veins, (134. *a. a.* 120. B. *f.*) and transmitted directly to the auricle, (134. *c. c.* 120. B. *h.*) without passing through the gills with the venous blood of the system. The systemic veins follow nearly the course

of the systemic arteries, having their great trunks disposed along the dorsal part of the body beneath the aortæ, and around the margin of the mantle interior to the palleal arteries, and in a similar manner the branchial arteries closely accompany the branchial veins in their distribution over the laminæ of the gills. Several enlargements are observed on the vascular system of conchifera, as in higher mollusca, and in some of the articulated tribes. The principal venous trunks from the viscera appear to distribute their blood through the reticulate tissue of a reniform organ, near the heart, before it is collected into the two great lateral branchial sinuses, like those of crustacea or the branchial auricles of cephalopods, from which the branchial arteries arise. This minute distribution of the visceral venous blood, like a renal portal circulation, before being transmitted to the gills, may assist in its aeration or afford the materials of some secretion, and the principal trunks of the palleal veins return directly to the auricles, along with the aerated blood transmitted by the veins of the branchiæ. So that although the whole of the systemic blood is not transmitted through the branchial organs of conchifera the advantage of a complete double circulation is nearly secured to these animals by the free exposure to the surrounding element, of that portion which is distributed over the extensive folds of the mantle.

From the undivided condition of the auricle and ventricle in most of the *gasteropods*, and the uniform systemic character of these cavities, there is greater simplicity in the general form of the sanguiferous system in this class than in the inhabitants of bivalve shells. As they present however, remarkable differences in the form, the position, and the nature of their respiratory organs, and differ not less in the general form of their body, these circumstances materially influence the less important peripheral parts of the vascular system. The respiratory organs being generally unsymmetrical, and confined to one side of the body, there is no longer necessity for division of the cavities of the heart, and this organ is therefore commonly single and lateral in its position. It consists, as seen in the annexed figure (Fig. 135.) of the *harpa minor*, of a distinct muscular auricle, (135 *b.*) which receives the arterialised blood from the respiratory organs, (135. *f.*) and of a systemic ventricle, (135. *c.*) which trans-

mits it through a bulbus arteriosus to a great anterior, (135. *e.*) and posterior (135. *d.*) aorta as in conchifera. These two

FIG. 135.



cavities are compactly enveloped in a tough pericardial covering, (135. *a.*) their parietes are strengthened by numerous crossing fasciculi of muscular fibres, and their apertures are well protected by valvular folds. From the varying position of the respiratory organs, the heart is sometimes placed on the right side of the body, sometimes on the posterior or the anterior part of the back, but most frequently towards the left side, and it has commonly a pyramidal or a conical form, with its base, formed by the capacious auricle, directed towards the respiratory organs, and its apex, formed by a strong and angular ventricle, like that of fishes, and a dilatable bulbus arteriosus, directed towards the systemic aorta. The auricle is divided into two parts in the *halyotis*, the *fissurella*, and the *emarginula*, as in the conchiferous animals, and the ventricle of the heart is also perforated by the rectum in these genera, as in the former class. In the *halyotis* the arterialised blood returning from two long pectinated branchiæ is conveyed by two corresponding veins to two lengthened auricles placed on the left side of the body, and much resembling those of most conchifera. From these cavities it is poured on each side into a lengthened fusiform single ventricle placed between them, provided with strong muscular parietes and fleshy columns, and completely embracing the intestine which passes through its cavity. The ventricle indeed, appears externally as only an enlarged or thickened portion of the intestine, to the sides of which the auricles are

attached, and all these cavities of the heart are inclosed in a distinct pericardium. The great aortal trunk is here given off from that extremity of the ventricle, which the intestine first perforates, and in passing inwards it sends off large arterial branches to the abdominal viscera, to the round muscle of attachment, like that of a spondylus or an ostrea, which fixes the *halyotis* to its convex shell, and the vessel then continues forwards to supply the parts of the head, so that this animal presents the nearest approach to the conchifera in its mode of circulation. A similar division of the auricle was observed also by Poli in the *chiton*, where each division appears to communicate by two distinct openings with the ventricle. The passage of the intestine through the heart, thus so frequent in conchifera and gasteropoda, may add by exosmosis further nutriment to the blood, where an absorbent system distinct from the veins is not yet developed, or may assist in excreting some material from the blood into the anal portion of the intestine, before that fluid is distributed for the nourishment of all parts of the body. It is obvious also that the constant contractions of the muscular ventricle, compactly embracing the inert terminal part of the intestine generally charged with the residue of digestion, must mechanically assist the passage of that matter through the canal.

As the branchiæ in the naked *tritoniæ* are disposed along the sides of the upper part of the body, the heart, consisting of a single auricle and ventricle, is situated between these organs in the middle of the back, and the aortal trunk proceeding from the fore part of the ventricle, divides at its origin into three principal branches, the posterior of which is distributed chiefly on the genital organs, the middle branch on the digestive, and the anterior larger branch on the muscular and sensitive organs of the anterior and lower parts of the body. In other genera where the branchiæ are thus disposed equally on the two sides, as in *scyllæa*, *tethys*, and others, the cavities of the heart have the same position as in the *tritonia*; but when the gills are confined to the left side of the body, as in the great order of pectinibranchiate gasteropods, the heart is found to occupy the same side, as seen in the *buccinum undatum*, (Fig. 22.) where the arterialised blood from a larger (22. *g.*) and a smaller (22. *i.*) pectinated

branchia on the left side, is transmitted to a capacious thin auricle and a thick muscular ventricle (22. *h.*) on the same side, to be distributed through the system by the great anterior and posterior aortal branches. The auriculo-ventricular orifice is here protected, as usual, with two very distinct semilunar folds, in the position of the mitral valves of mammalia. The aorta immediately divides into several large trunks which proceed forwards to the œsophagus and head, upwards to the large muciparous follicles and the mantle, and backwards to the digestive and the generative organs. The branchial tufts of the *doris* being placed around the anus and protected in the same cavity of the mantle, the heart is here situated on the median and posterior part of the back, and receives the aerated blood from the gills into a crescentic auricle disposed around the rectum, nearly as the ventricle of conchifera. The short round muscular ventricle is here placed anteriorly to the auricle, and gives origin to a large median aortal trunk which advances forwards along the back to the head, sending off large branches to the liver, the intestine, the genital organs, and other parts in its course. In the pulmonated gasteropods, as the *helix*, *lymnæa*, and other genera, and in many which breathe by gills as the *aplysia*, *bullæa*, and others, the respiratory organs, and consequently also the heart, are placed on the right side of the body. The arterialised blood of the *aplysia* (Fig. 121.) collected from the numerous laminæ of the gills (121. *p.*) under the right margin of the mantle, is received into a capacious auricle (121. *q.*) and thence into a strong muscular pyriform ventricle, (121. *r.*) like that of many fishes. The *bulbus arteriosus* (121. *r. h.*) is of a lengthened form like that of plagiostome fishes, and when injected or inflated appears transversely sacculated, which induced Cuvier to believe that it was surrounded with lateral arterial loops communicating with its cavity and destined to secrete the fluid of the pericardium. The aorta gives off a large hepatic (121. *o.*) and gastric (121. *h.*) artery, and then directs its course downwards to advance and distribute its branches along the ventral part of the body. The dilatable and sacculated portion of the aorta, which appears somewhat analogous to the numerous transverse valvular folds in the *bulbus arteriosus* of plagiostome fishes, here extends beyond the origins of the hepatic and gastric arteries.

The venous blood collected from all parts of the system in the aplysia is transmitted to the branchial arteries by two wide venæ cavæ, with thin membranous parietes; and on opening these two venous trunks, superficial depressions are observed on their interior thin coats, corresponding with the interstices of the surrounding muscular bands of the abdomen. These depressions perceived on the serous lining of the great systemic veins of the *aplysia* have been supposed to be remarkable perforations leading into the general cavity of the peritoneum, and probably serving the function of emunctory or absorbent orifices, and the same anomalous structure has been ascribed to the great systemic veins of the nautilus. The serous lining of these wide veins of the aplysia, however, was shown by Meckel to be entire, as in other animals. In the testaceous and naked pulmonated gasteropods, where there is no canal nor syphon on the left side, and in which the respiratory sac, though opening on the right side, extends across the median plain, the two cavities of the heart are directed transversely to the left side, between the pulmonary cavity and the large muciparous gland, and the aorta immediately divides into two great trunks, which send branches to the abdominal viscera and the muscular parts. The auricle is perforated by the two trunks of the pulmonary veins, and two semilunar valves are seen in the ventricle at the auriculo-ventricular orifice. The inferior of the two aortic trunks is distributed chiefly on the liver and on the ovary; the ascending trunk gives a branch to the stomach and intestine, the right tentaculum, the dart-gland, and the genital ducts; another to the stomach, the salivary glands, and œsophagus, and the continuation of the trunk, after furnishing a branch to the left tentaculum, turns backwards to spread its terminal branches on the large muscular foot. The venous blood collected from the system into a single vena cava, is transmitted by the ramifications of two pulmonary arteries over the interior surface of the respiratory sac, and the capillaries reunite to form the two pulmonary veins which enter the auricle of the heart.

The structure and position of the heart, and the general distribution of the blood-vessels, appear to be the same in the *pteropods* as in the higher gasteropodous mollusca; the venous blood of the system is propelled through the external

branchiæ, and, thus aerated, is conveyed to the single auricle and ventricle to be distributed to all parts of the body. The thin, transparent, and tough pericardium inclosing the heart of the *clio borealis*, as shown by Eschricht, lies towards the right and posterior part of the abdominal cavity, with its broadest part behind, and its apex directed forwards. The ventricle, about half a line in length, is in form of a truncated triangular pyramid, with rounded angles, as in many gasteropods and fishes; its parietes are thick and its cavity small, it gives origin to the aorta at its tapering anterior apex, and communicates posteriorly with the thin membranous auricle placed at its base. The aorta, on perforating the pericardium, continues its course forwards, sending branches, as in the gasteropods, to the liver and genital organs; and advancing towards the head, gives off minute arteries to the neck and to the large muscular lateral fins. The heart lies also on the right side of the abdominal cavity in the *hyalea* and *pneumodermon*, and consists of a single systemic auricle and ventricle, inclosed in a thin transparent pericardium, as in the *clio* and in most of the cephalous mollusca; and the arterialised blood is returned from the respiratory organs by the branchial veins to the auricle and ventricle, to be distributed through the body.

The bilateral symmetry of the *cephalopods*, so conspicuous in their osseous and muscular systems, in their motor and sensitive columns and nerves, and in their organs of sense, is not less obvious in their respiratory and circulating apparatus, and forms a closer link of connexion between them and the fishes and other vertebrated classes, than is observed in the inferior mollusca. The auricle in the naked cephalopods, as in the conchifera, is divided into two similar and separate muscular cavities, which here receive, as in fishes, the venous blood of the system before it is transmitted to the respiratory organs. The ventricle is single and systemic, as in the other molluscous classes, median in its position, placed with the auricles in the middle of the abdominal cavity, and receives the arterialized blood from the branchiæ, to be transmitted by an anterior and a posterior aortal trunk through the body. The venous blood collected from the capillaries of the arms and suckers, is returned by the interbrachial veins to an irregular, transverse, circular trunk

formed by their union, and surrounding the head anterior to the eyes and beneath the external muscular aponeurosis of the connecting membrane of the arms. The interbrachial veins are formed by the union of the two contiguous lateral veins of each pair of arms, as seen in the octopus ; and the two lateral portions of the circular cephalic vein uniting in front, behind the syphon, to form the great anterior vena cava, have each an internal semilunar valvular fold defending the orifice leading into the cava. The trunk of the superior cava continues its course downwards or backwards, on the left side of the intestine, and exterior to the muscular aponeurosis embracing the liver, receiving venous branches from the syphon, the fore part of the liver, and the muscular parietes of the mantle. After a short course along the front of the liver the vena cava bifurcates, and its two branches proceed laterally to the two divisions of the auricle placed at the base of the branchiæ. The muscular cavity of each of these auricles is preceded by a perceptible sinus venosus, as in the auricle of most fishes; they have often a dark or blackish colour, like the auricles of many conchifera, and in the naked tentaculated species, erroneously designated decapoda, there is a small hollow fleshy appendix communicating by a short tubular cervix, with the cavity of each auricle. The exterior appendices of the auricles are not found in *loligopsis*, *octopus* nor *nautilus*.

The trunk and bifurcation of the vena cava are covered with saccular vesicles, cellular internally, which communicate freely with the cavity of the veins, and are lodged with them in the same two membranous thoracic venous cavities. They form two bifid clusters on each side in the nautilus as described by Chiaje. The wide membranous cavities, containing these venous branches and vesicles, communicate by two lateral tubular openings with the general cavity of the mantle, and thereby with the exterior medium ; and these cellular vesicles may thus be destined to secrete or absorb some materials to affect the constitution of the blood. Each lateral auricle, like the systemic ventricle, is here enclosed in its distinct pericardium, and each sinus venosus receives, besides the branch of the vena cava, a large lateral palleal vein, returning the blood from the corresponding side of the mantle and the suspensory ligament of the branchiæ. The venous blood is returned from the different

organs of the abdomen by two great visceral veins, or posterior venæ cavæ, which enter the two bifurcations of the anterior cava near their commencement, and at an obtuse angle calculated to retard the flow of the blood. The visceral vein of the right side is formed chiefly by branches from the right inferior part of the liver, from the intestinal canal, and from the genital organs; the left visceral vein receives its branches from the left side of the liver, from the stomach, and from the œsophagus. The great trunks of the two visceral veins are also surrounded with vesicular appendices opening freely into their interior, as the two branches of the cava.

The two lateral auricles, of a dark grey colour and loose cellular texture, placed at the base of the branchiæ, and receiving all the venous blood of the system, are entirely foraminated or deeply pitted on their inner surface, provided with two mitriform valves at the opening from the sinus venosus, and tapering towards the commencement of the branchial arteries, where they are generally provided with minute valves, as in sepia, loligo, and argonauta. In *loligopsis*, the usual detached venous vesicles are collected into four pyriform clusters placed on the trunk and branches of the anterior cava; and instead of the usual sinus venosi at the entrance of the branchial auricles, the venæ cavæ are here surrounded by a spherical cluster of similar vesicles; and the same spherical clusters of vesicles are observed to surround the four branches of the anterior cava in the *nautilus*, where the branchial auricles have not been observed, but the usual valves are seen at the commencement of the four branchial arteries. The branchial arteries, two in the naked cephalopods and four in nautilus, corresponding with the number of branchiæ, follow along the dorsal or fixed margin of the gills between the suspensory ligaments and the pectinated laminæ of these organs. The branchial artery of each gill is remarkably wide and capacious, and gives off two lateral rows of branches which extend ramifying along the inner margins of the branchial laminæ. The branchial nerve and the nutritious artery and vein of the gill accompany the branchial artery along the free margin of the musculo-ligamentous band which supports the gill.

The arterialized blood is collected from the branchial laminæ by their peripheral venous branches which unite on

the free margin of the gills to form the wide trunk of the great branchial vein of each organ; there are thus two branchial veins on each side of the body in *nautilus*, and one in the naked cephalopods. The branchial veins are directed inwards to the median plain, to enter the great systemic muscular ventricle, and generally dilate to form a perceptible sinus on each side, immediately before entering its cavity. The systemic ventricle is larger, and more muscular in its parietes than the branchial auricles, and is extended, sometimes transversely, sometimes longitudinally in the middle of the visceral cavity, enclosed in its pericardium, and situated behind the venæ cavæ and between the auricles. In *sepia*, *loligo*, *octopus*, and *nautilus*, the systemic ventricle is extended transversely, and the branchial veins enter its lateral extremities. In *sepiola* it is pyriform and subtransverse, and in *loligopsis* it is of a lengthened fusiform shape, extended longitudinally, and receives the branchial veins on each side of its widest middle part. The branchial vein, like the branchial artery, is wide as a sinus in its course along the margin of the gill, and contracts its calibre at the base of that organ. Two semilunar valves at the entrance of each branchial vein into the systemic ventricle, prevent the return of the blood into these veins during the contraction of the heart; two semilunar valves are also placed at the orifice of the great anterior aorta. The systemic ventricle is more capacious than both the branchial auricles; it is provided with thick and firm muscular parietes, and the prominent fleshy columns give a cellular appearance to its inner surface. The muscular enlargement of the bulbus arteriosus is obvious at the origin of the great anterior or cephalic aorta, as in most of the lower molluscous classes and the cold-blooded vertebrata. Two other arteries are given off from the same systemic heart, one of which, directed backwards, is distributed on the genital organs which occupy the bottom of the abdominal sac, and the other forming a posterior aorta or palleal artery, is ramified chiefly on the intestine and the muscular parietes of the mantle. The anterior or cephalic aorta arises from the posterior part of the heart, and at its origin is directed backwards and to the right between the peritoneal folds which separate the intestinal from the gastric sacs. It passes to the right of the cardiac orifice of the giz-

zard, and penetrating a foramen of the muscular diaphragm, it ascends on the right side of the œsophagus, in the dorsal cavity behind the liver, as far as the œsophageal opening of the cranium. Near its commencement this great trunk gives off a peritoneal branch, then two dorsal palleal branches, then some twigs to the gizzard, a little higher a branch to the intestine and stomachs, and two branches to the liver. Continuing upwards behind the liver, it sends off several branches to the superior dilatation of the crop in the octopus, and escaping from the dorsal cavity it divides into two trunks, which encompass the œsophagus, like the two trunks of the aorta in most cold-blooded vertebrata, or the first branchial arch formed by the aorta in the embryos of higher warm-blooded species. From this arterial œsophageal ring two branches proceed upwards through the cranial aperture, to supply the buccal apparatus and the upper pair of salivary glands, and two larger branches, which pass downwards behind the liver to ramify on the large inferior pair of salivary glands and on the crop. The two trunks of the œsophageal ring penetrate together the fore part of the cartilaginous cranium, and then ascend, slightly diverging, to the bases of the muscular arms, where each trunk divides into four branches, like four branchial arches, which accompany the brachial nerves, ramifying symmetrically along the central cavities of the eight arms.

The smaller aorta arises from the anterior or ventral aspect of the heart, and immediately sends off two lateral branches to supply the numerous glandular vesicles of the great venous trunks. Another considerable branch from this artery ramifies on the intestinal canal, and sends twigs to the adjoining folds of the peritoneum; but the principal trunk continues its course forwards in front of the great vena cava, and extending along the anterior connecting band of the mantle, ramifies on the muscular parietes of that cavity. The third arterial trunk originating from the heart, proceeds from its inferior surface, and is directed backwards, to ramify on the testis of the male or the ovarium of the female, and varies in its development, as in other animals, according to the periodical changes in the condition of these organs.

The absence of valves at the origin of the branchial arteries in the *octopus*, is compensated for by the greater muscu-

larity of the branchial hearts in that genus. In the *loligopsis* the two aortal trunks come off from the anterior and the posterior apex of the longitudinally extended ventricle, both have a slight bulbous enlargement at their origin, and the genital artery forms merely a branch originating, from the commencement of the great dorsal or cephalic aorta. So that in this highest of all the invertebrated classes, only two of the great cavities of the heart, a ventricle and an auricle, are yet distinctly developed; and notwithstanding their diversities of form and their occasional division, these two cavities continue with great regularity throughout the molluscous subkingdom.

FIFTH SECTION.

Sanguiferous System of the Spini-Cerebrated, or Vertebrated Classes.

There is great uniformity of plan in the different conditions presented by the vascular system in the vertebrated classes, and in the several phases of development through which it passes before arriving at its perfect form in each of the divisions of this subkingdom. The heart is always situated on the anterior or ventral aspect of the alimentary canal, and its compartments are always contiguous and enclosed in a distinct pericardium. In the species which breathe solely by branchiæ, whether permanent or deciduous, the heart consists of a single auricle and a single ventricle, which are at once branchial and systemic, and the blood is entirely propelled by it through these respiratory organs. But in all the pulmonated tribes there is a distinct auricle superadded, for the reception of the aerated blood from the lungs; and in the hot-blooded classes there is always a bilocular heart for the pulmonic blood, and a similar heart for the systemic, which have no communication with each other, though enclosed in the same pericardium, and formed by the subdivision of the same original cavities. The heart increases in bulk as we ascend in the vertebrata, being smallest in the fishes, amphibia and reptiles, and largest in the hot-blooded tribes; and there is always a hepatic portal circulation, which increases in extent as we advance from the lower

to the higher classes, and as we ascend through the successive stages of the development of the same species. The blood contains more fibrine and red globules than in the invertebrata, and its colour is always red, being of a much deeper hue in the mammalia and birds than in the cold-blooded classes, especially in the fishes, where it is also less extensively circulated through the body.

As fishes move and breathe in a dense element, where the air is less abundantly supplied to oxygenate their blood, and as their respiration is still effected by branchiæ, as in most of the invertebrated classes, the heart is placed on the branchial and not on the systemic portion of their great aortal artery, and by contributing its impulse to the movement of the branchial blood, the extent of respiration is increased beyond that of the aquatic mollusca, where the heart is entirely systemic. The extent and the activity of their muscular system render less necessary, in fishes and in the tadpoles of amphibia, an exclusively systemic heart to propel the blood through the body, that being greatly effected by their active movements; and the most active period of the amphibia is the tadpole state, when the heart is entirely appropriated to the branchial ramifications of the great aortal trunk, as it is to the branchial arches of this vessel in higher embryos.

The venæ cavæ of fishes generally unite to form a sinus venosus between the tendinous diaphragm and the auricle, and this sinus is often a capacious muscular pulsating cavity, like the auricle, as in the rays. Two crescentic valves commonly defend the entrance of the sinus venosus into the auricle, to prevent the return of the blood during the contraction of the latter cavity. The heart, like the respiratory organs, is situated far forwards under the head, between the anterior terminations of the branchial arches; it consists of a thin, wide capacious auricle, and a small muscular ventricle, which are enclosed, along with the bulbus arteriosus, in a thin pericardium. The heart is placed farther backwards from the head in the cartilaginous than in the osseous fishes, and still more in amphibia and in higher vertebrata. The two cavities of the heart are not placed in the same continuous straight line as in the gasteropods and other mollusca, and in the earlier conditions of the vertebrated embryo; the auricle is

here extended above the ventricle, and it advances more forwards over the ventricle in the plagiostome fishes, as the rays and sharks, than in the osseous and inferior fishes, where it has undergone a less deviation from its primitive embryo position. In higher classes the auricles advance to the anterior part of the ventricles, and the whole are compactly embraced in a small pericardial cavity. The cavity of the pericardium, in the plagiostome fishes, communicates by distinct openings with the peritoneal cavity of the abdomen, and, by means of the two lateral anal orifices, with the exterior medium, as in the cephalopods; and the heart and bulbus arteriosus of the sturgeon are covered with a loose glandular mass, like the glandular vesicles enveloping the venæ cavæ of the cephalopodous mollusca.

The auricle is more capacious and has thinner muscular parietes than the ventricle, and it generally extends so much transversely as to envelope the upper or dorsal side of the ventricle, and to appear beyond it on each side, or to surround it entirely during its own diastole. Although the margins of the auricle are often angular, they do not develope the fringed auricular extensions common in higher classes, and the muscular bands form distinct fleshy columns in the inner surface. The auriculo-ventricular orifice is situated near the anterior and superior part of the ventricle, and is furnished with two strong semilunar valves, with loose free margins, like those of the auricular orifice of the sinus venosus. Sometimes these folds of the ventricular orifice, or mitral systemic valve of the hot-blooded vertebrata, consist of three or four parts, and in the cartilaginous fishes their margins are strengthened by connecting tendinous cords. The ventricle is comparatively small, but with thick muscular parietes often separable into two laminæ, and has generally an angular and tapering or pyramidal form, in the osseous fishes, being broad, oblique, and flat towards the tendinous diaphragm, and becoming smaller towards the anterior opening into the bulbus arteriosus. In the higher cartilaginous fishes the ventricle is more rounded, depressed and extended transversely, like that of chelonia—a preparation for the longitudinal division of this cavity into two parts, which is gradually effected in the class of reptiles. Its interior is provided with thick, prominent, fleshy columns; its colour

is lighter than that of the auricle, and darker than that of the bulb, which is often white; and its opening into the bulbus arteriosus, or thick muscular origin of the branchial artery, is defended by two semilunar valves, which prevent the return of the blood into the ventricle, and support the column of that fluid during the contraction of this muscular part of the great aortic or branchial artery. The bulbus arteriosus is sometimes of an ovate form, like an additional ventricle appended to the heart, as in most osseous fishes, and sometimes cylindrical, as in the chondropterygii, where it is furnished internally with several longitudinal rows of transverse valvular semilunar folds, besides the usual valves at its origin. The simple semilunar form of the valves throughout the heart of fishes is similar to that observed in the valves of the heart in the invertebrated classes, and in those of the veins, lacteals, and lymphatics in the highest vertebrata. The muscular arterial bulb, anterior to the ventricle, is obvious in the acephalous and the cephalous mollusca, as in the fishes, and prepares this great arterial trunk for its division into a systemic and a pulmonic vessel in the higher classes of air-breathing vertebrata.

By the contractile force of these muscular cavities of the heart, the blood of fishes is propelled, as in the embryos of all higher vertebrata, into a single great arterial trunk divided on each side into branchial arches, which here however ramify to minute capillaries, and constitute extensive respiratory organs adapted to the element in which these permanent larvæ are destined to reside. No branches, however, are observed to come off from the trunk of this great branchial artery, to be distributed on the rudimentary lungs or air-sac of fishes, as are seen in higher classes of cold-blooded vertebrata, where the lungs are more distinctly subservient to respiration than in this class. In order to prevent the return of the venous blood, during the contraction of the muscular bulb at the origin of the branchial artery, the interior of that part of the vessel is furnished in the cartilaginous fishes with numerous small semilunar valves disposed in longitudinal rows, which vary in number in different species, as also the number of valves in each row. These valves are often provided with tendinous cords to perfect their function, and preserve the regular flow of the blood forwards during the violent exertions of these muscular fishes. Some

sharks have only two rows of valves, others have three, and there are five rows in the bulbus arteriosus of the skate; in the sturgeon there are two rows of small valves near the ventricle, and a third row of larger valves at the anterior termination of the muscular bulb, each row having four valves, and all are placed in symmetrical order.

The branchial artery conveys the entire venous blood of the system, and divides into lateral trunks corresponding with the number of the branchiæ on each side, which are only ramifications of these primary trunks. There appear to be at first generally five branches on each side in this class, as in the branchial arches of the aorta in the embryos of higher vertebrata; and in most of the chondropterygii these five pairs of branchial arteries and gills continue in the adult state; but in the osseous fishes the anterior pair are obliterated and converted into carotid arteries for the head, while four pairs are retained for distribution on the four pairs of persistent branchiæ. The branchial artery conveying the venous blood of each gill, occupies the exterior portion of the groove of the osseous or cartilaginous hyoid arch, and the corresponding branchial vein, returning the arterialized blood, runs more concealed in the deeper part of the same marginal groove. The branchial arteries ramify to an extreme minuteness on the delicate bifid laminæ of the gills, and their capillaries are continuous with those of the branchial veins. The deciduous external respiratory filaments of many cartilaginous and some osseous fishes, being merely prolongations of the permanent internal branchial laminæ, their arteries and veins are the same. The venous branches, reinforced by a continued accession of twigs from the branchial laminæ, proceed upwards to the dorsal ends of the branchial arches, and receiving all the arterialized blood from the gills, they unite to form larger trunks, which extend backwards, and anastomose to form the single great dorsal artery or abdominal aorta. The anterior pair of branchial veins thence appear to give off, at their dorsal part, the carotid arteries to the head, which is thus supplied with blood newly arterialized by passing through the gills. The succeeding pairs of branchial veins also send off arterial branches, which proceed forwards to be distributed on the heart, the pericardium, the operculum, and the surrounding parts. The principal trunks, however, of the branchial veins unite below

the bodies of the dorsal vertebræ, to form the abdominal aorta, which continues its course backwards along the median plane, beneath the vertebræ, to the coccygeal region, where it becomes enclosed during the rest of its course, by the inferior converging laminæ of the coccygeal vertebræ.

The great cœliac artery which supplies most of the abdominal viscera, arises from the commencement of the aortal trunk formed by the union of the branchial veins, and sends off numerous branches, which ramify extensively on the stomach and intestines, on the liver, the spleen, the air-sac, and the genital organs. From the principal trunk of the aorta, within the cavity of the abdomen, and behind the great visceral artery, several lateral branches come off at regular distances, one pair for each vertebra, which supply the contiguous muscular, osseous and cutaneous parts, and send down branches as renal arteries to the long, narrow, lobulated kidneys, extended along the sides of the vertebral column. The brachial arteries, for the pectoral fins, originate from the aorta near its commencement, and two femoral arteries likewise come off from the aorta in the region of the pelvis, for the ventral fins. The cœliac artery sometimes originates from the common trunk of the right branchial veins before it unites with the left to constitute the aorta. The posterior continuation of the aorta extends single along the inferior ring of the coccygeal vertebræ, above the venous trunk which occupies the same canal, and it sends off regular pairs of intervertebral branches which pass upwards and downwards on each side, to supply the muscular and other parts of the tail.

The venous blood collected from the lower and posterior coccygeal region of fishes, is received by numerous pairs of lateral branches, which convey it into the inferior caudal vein, enclosed in the lower rings of the coccygeal vertebræ. This inferior caudal vein lies below the great arterial trunk, enclosed in the same inferior vertebral rings, and conveys the venous blood from the cutaneous and muscular parts of the tail forwards to the abdomen. It forms the commencement of the great posterior vena cava, it continues its course along the abdomen, under the bodies of the dorsal vertebræ, and under the trunk of the abdominal aorta, collecting the venous blood chiefly from the surrounding muscular parts, and it terminates in the great sinus venosus behind the auricle of

the heart. The posterior commencement of this venous trunk in the eel was observed by Hall to present a small pulsating muscular sinus, which accelerates the flow of the blood towards the abdomen. The venous blood received from the upper cutaneous and muscular parts of the coccyx, is conveyed by numerous lateral branches into a superior caudal vein, contained within the upper rings of the vertebræ, and above the spinal chord in the same canal. The lobulated kidneys extending along the whole abdomen to the head, exterior to the peritoneum, and attached by cellular substance and vessels to the sides of the bodies of the vertebræ, receive numerous branches, and nearly the whole blood of this superior caudal vein extending forwards above the spinal chord. This venous blood transmitted through the lobes of the kidneys by the superior vein, is received from the capillaries by lateral descending branches, which convey it into the inferior venous trunk, to be carried forward to the sinus venosus, thus forming a renal portal circulation, like the portal circulation of venous blood through the liver. But the posterior part of this vein also communicates, by direct branches, with the inferior caudal vein.

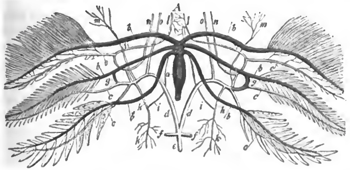
The venous blood collected from the chylopoietic viscera of the abdomen, is sent to be distributed through the large and divided liver by a variable number of trunks, forming so many venæportæ; and sometimes the long lobes of the liver, attached between the turns of the intestine, receive the separate venæ portæ more directly from the mesenteric veins. Sometimes only a part of the venous blood from the viscera is conveyed through the liver, and a part is transmitted to the vena cava, as by a ductus venosus in higher embryos. The lungs of fishes, as in the embryos of higher classes, not being employed for respiration, they are nourished by the great visceral artery, like other organs of the abdomen, and their venous blood is transmitted by the portal veins through the liver, or sometimes is carried directly to the vena cava. This is a more simple form of the hepatic portal circulation than is found in higher classes, where these visceral venous trunks generally unite to form one great vena portæ before entering the liver, and it more resembles the divided condition of the venous portal circulation through the kidneys of fishes. In the *thynnus vulgaris* Eschricht observed the liver to be composed

of plexuses of parallel blood vessels, derived from the portal vein, the hepatic artery, and the hepatic vein, the minute lobules of the organ being formed by straight blood canals opening into sinuses, like the numerous approximated, parallel, pancreatic follicles of osseous fishes. The hepatic vein sometimes forms a distinct sinus between the diaphragm and the liver, as in the rays, where there are also two lateral posterior venæ cavæ with enlargements in their course. The two anterior venæ cavæ extend, like jugular veins, along the sides of the neck, receiving the venous blood from the head, the pectoral fins, and the anterior parts of the trunk, and frequently form a sinus, by their union behind the head, before they open, with the posterior cavæ and the hepatic veins, often three in number, into the common sinus venosus, between the pericardium and the tendinous diaphragm. In many fishes there are two hepatic veins, and in others they unite into a single trunk, as in most higher animals. So that the vascular system of fishes is advanced not only by the development of a distinct chyliferous and lymphatic system of vessels, but also by that of a more or less extensive hepatic and a renal circulation of venous blood, which have not been traced in the invertebrated classes.

The amphibious animals commence their career as fishes, having in their tadpole state but one auricle and one ventricle of the heart, breathing by means of gills, and sending the whole of their blood through the branchial arches of the aorta as in the adult state of the finny tribes, and as in the embryos of all higher vertebrata. The heart of the tadpole, like that of the fish, consists of a thin capacious but muscular auricle, which receives the entire venous blood of the system, and a smaller muscular aud commonly rounded ventricle, which propels it into a distinct contractile fleshy bulbus arteriosus, as seen in the larva of the *triton cristatus*, (Fig. 136. *a.*) From the bulbus arteriosus, or commencement of the great aortic trunk, the venous blood is conveyed by three or more lateral branches, or branchial arches, on each side, (136. *b*, *b*, *b*,) both into the first and more deciduous external branchiæ, and into the later and more durable internal forms of these organs, as into the deciduous external filamentous and the permanent internal laminated branchiæ of plagiostome fishes. The number of branchial arteries on

each side corresponds with that of the branchial organs when developed; they are generally three in number; at first they do not appear to communicate with the trunks of the branchial veins by anastomosing canals at their base, their trunks being nearly or entirely occupied in the formation of branchial capillaries, and this fish-like character of the branchial arteries of the young tadpole was found by Cuvier also in the adult *siren*, where the whole blood is thus forced through the gills. The arterialised blood returning

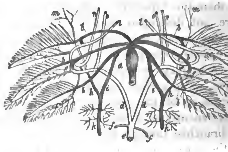
Fig. 136.



from the gills of the tadpole by the anterior branchial veins, (136.*c. c. c.*) is in part sent, as in fishes, by ascending branches, (136. *l. m. n. o.*) to the head and anterior parts of the body, while the rest is collected into larger trunks, (136. *d. d.*) which unite to form the descending aorta, (136. *e.*) At an early period of the development of the tadpole, however, minute anastomosing canals are formed or enlarged between the great trunks of the branchial arteries and those of the branchial veins, (136. *b. b. g. g,*) by which a preparation is made for the gradual obliteration and absorption of the whole branchial apparatus; and the same canals of communication between these trunks are found to exist in nearly all the perennibranchiate forms of amphibia in their adult state. From the posterior branchial artery on each side, conveying venous blood in the earliest condition of the tadpole, a minute branch (136. *i. i.*) descends to the rudimentary lungs, and in its course unites with an anastomosing trunk (136. *h. h.*) from the posterior branchial veins conveying the arterialized blood from the gills, to supply these pulmonary organs.

During the progress of the metamorphosis from the tadpole or larva state, the vessels proceeding to the head and neck enlarge, as seen in the second stage of the *triton cristatus*, (Fig. 137. *l. m. n. o,*) the anastomosing canals (137. *b.b. g. g,*) between the trunks of the branchial arteries and veins, increase in size, the capillary ramifications of the gills (137. *c. c. c.*) become diminished, obliterated, and absorbed; and the small branches on each side proceeding from the posterior branchial arteries to the lungs, form considerable pulmonary arteries, (137. *i. i.*) which ramify over the increasing surface of these now important respiratory organs, (137. *k. k.*) The venous blood of the system is now therefore conveyed in greater quantity and by a more direct course, from the bulbus arteriosus (137. *a,*) through the communicating trunks of the branchial arteries and veins (137. *b. b. g. g.*) to the branches

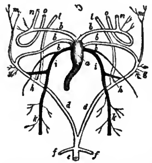
Fig. 137.



and trunk of the descending aorta. (137. *d. d. e.*) The two arterial trunks formerly (136. *h. h.*) conveying arterialized blood from the branchial veins to the air-sacs or rudimentary lungs, now become small ductus arteriosi (137. *h. h.*) connecting the pulmonary arteries (137. *i. i,*) with the branches (*g. d. g. d.*) of the abdominal aorta, (137. *e.*) This is nearly the condition in which the perennibranchiate species have the development of their vascular system permanently arrested, where the respiration is effected equally by pulmonic and branchial apparatus in the adult state. By the further metamorphosis of these vessels during the development of the caducibranchiate amphibia, it is manifest that the anterior pair of branchial arteries are gradually converted into

the great arterial trunks which proceed to the head and neck, as seen in the third stage of the *triton* (Fig. 138. *n. n. o. o.*) where the branchiæ have been entirely absorbed, and these cephalic vessels have acquired a less tortuous course. The second pair of branchial arteries are converted into the right and left branches of the abdominal aorta (138. *b. d. b. d.*), and the posterior pair of branchial arteries become the two pulmonary arteries (138. *i. k. i. k.*) conveying mixed blood from the heart to the lungs. The development of the great aortic trunks, from the previously formed branchial arches, is effected in a similar manner, but according to a simpler plan, in all the higher classes of vertebrata, as in them the capillary ramifications for an aquatic respiration are not developed from the branchial arches. The anastomosing canals, therefore, observed in nearly all the amphibia, between the trunks of the branchial arteries and branchial veins, may be regarded as the continuations of the primitive aortic arches, temporarily reduced in size during the presence of the gills in the caducibranchiate forms, and permanently kept open in those species which preserve the branchiæ through life; whilst in fishes, and apparently in the siren, the aortic arches are entirely divided into branchial capillaries, through which the whole blood of the system is necessarily conveyed to increase the extent of their aquatic respiration. The capillary branches of the branchial arteries in the external gills of the tadpoles, do not form ramifications as in the corresponding vessels of fishes, but minute arches or loops which pass singly around each small leaflet of the ramose branchiæ. Although the branchial arteries, after the metamorphosis of the frogs, and after the functions of these vessels have changed, appear to coalesce, and to originate on each side of the bulbus arteriosus by a common trunk, they are yet found in the adult state to preserve their three canals distinct to their origin, being separated from each other by internal septa which are discovered on opening the two primary trunks of the aorta.

FIG. 138.



The bulbus arteriosus is considerable in the adult proteus, and gives off, not only the three branchial arteries on each side to the external gills, but also an aortic arch on each side which unite together to form the trunk of the aorta, as shown by Rusconi—thus combining in the same animal, the vascular conditions of the tadpole and the adult of the caducibranchiate *amphibia*, or those of the fishes and the true *reptilia;* the same plan of structure appears to exist in the other perennibranchiate forms of this class. Even in the adult triton (138. *b. b. b.*) three aortic trunks continue to originate from each side of the aorta, the third pair (138. *i. i.*) being chiefly occupied in forming the two pulmonary arteries (138. *k. k.*) which communicate by small ductus arteriorsi (138. *h. h.*) with the arches of the abdominal aorta (138. *d. d.*) In the anourous amphibia, as the frogs and toads, the aortic arches still further coalesce by the metamorphosis, and externally appear to constitute, in the adult state, only a single great trunk on each side, divided internally by septa throughout its course, which gives off the usual cephalic, aortic, and pulmonic arteries; and while the external branchiæ in the tadpoles of these species are withdrawn, and are becoming absorbed, the branchial apertures, first on the one side of the neck and then on the other, become closed up by a thin fold of the skin which has been mistaken by some for the analogue of the opercular bones which support this part in fishes. Traces of the early branchial capillaries appear to be preserved on the carotid arteries through life, and the posterior or pulmonic arch of the aorta gives off an artery on each side to the back part of the head, as well as the great pulmonary arteries to the lungs. The branchial arteries in the young state of the *cæciliæ* are observed to ramify on internal gills, which open on each side of the neck by cutaneous apertures, as in the larvæ of other *amphibia*. The bulbus arteriosus in the *menopoma* (119. A.), is long, cylindrical, muscular and provided with numerous internal valves, as in the plagiostome fishes; these valves are disposed in two transverse rows, with four in each row, and the artery is dilated at the giving off of the aortic arches, which are four on each side. The small posterior or proximal aortic branches, on each side, are distributed chiefly on the simple pulmonary

sacs (119. A. *q*.), and they communicate by distinct ductus arteriosi with the next anterior or second branches of the aorta. The second and third aortic arches, of larger size, unite above the œsophagus (119. A. *o. o.*), like the branchial veins of fishes, to form the common dorsal trunk of the aorta (119. A. *f. f.*), and their united trunks on each side send off cephalic branches (119. A. *o. o.*) to the back part of the head, as in the former class. The fourth or most anterior pair, after giving off branches to the mouth, unite, behind the æsophagus, with the cephalic branches to be distributed on the head. The great aortic branches are nearly similar in the *amphiuma*, where the proximal arches are distributed chiefly on the long cancellated lungs, and the two succeeding arches unite above the œsophagus to form the descending aorta.

The heart of the larvæ, before the development of the lungs, consists, like that of the fishes, of a single auricle which receives the venous blood of the system, and of a single ventricle which propels it into the bulbus arteriosus and the branchial or aortic arches; but as development advances, and the air-sacs assume the functions of lungs, the arterialized blood collected from these pulmonary cavities, developes a small distinct sinus or left auricle on the united trunks of the two veins which return it to the ventricle. The existence of this smaller left auricle in the adult amphibia was first pointed out by Dr. Davy in the caducibranchiate species, as the frogs and toads, and the same structure of the heart was discovered by Weber, to pervade also the perennibranchiate amphibia, as the *axolotus* and the *proteus*. The left auricle, smaller than the right, is separated by a thin transparent septum from the larger systemic auricle, and is provided, like it, with distinct valves at its entrance into the ventricle. The venous blood of the system is generally collected into a distinct sinus venosus in amphibia, as in fishes, before it is transmitted to the large thin right auricle of the heart. The sinus venosus of the *triton* is a large round contractile cavity like the right auricle. The blood from the right and left auricles is mixed in the ventricle, by permeating the loose columnar structure of its parietes, and is prevented from returning into either aurcle, by small semilunar valves defending the

auriculo-ventricular orifices. The auricles are more advanced over the upper and fore part of the ventricle, than the aurcle even of the plagiostome fishes, and the whole heart, like that of fishes, is situated further forwards towards the head than in reptiles or the warm-blooded vertebrata. The ventricle was observed by Meckel to be partially divided by an internal septum extending from the apex in the *pipa*, as in chelonian reptiles, and he also observed the septum between the auricles in the *pipa*, the *siren* and the *axolotl*, without perceiving the difference of function in these cavities discovered by Davy and Weber in both these orders of amphibia. The sinus venosus of the right auricle and the bulbus arteriosus or commencement of the aorta, are here distinctly muscular and contractile, like the corresponding sinus and aortic bulb in the plagiostome and other fishes.

The two aortic trunks meet behind, under the vertebral column, as in reptiles, to form the abdominal aorta, at a point more or less advanced towards the head in different species, and in their course backwards, these two aortic vessels communicate with the trunks of the pulmonary arteries by means of the two ductus arteriosi. From the commencement of each of the two aortic trunks, a large artery originates, which divides into a brachial and a cephalic branch, to supply the corresponding arm and side of the neck and head, and these primary brachio-cephalic branches of the aorta, commonly supplying the anterior parts of the body in the amphibia, have the same size and mode of distribution on the right and left sides. The next great trunks from the arches of the aortæ, are the two pulmonary arteries, which descend on each side to ramify chiefly on the dorsal and median surfaces of the lungs, and which vary in size in different species according to the development of these pulmonary sacs. The bulb of the aorta often presents a rounded dilatation in the adult, corresponding with the part from which originated the branchial arteries of the larva. At the commencement of the great trunk of the abdominal or descending aorta, in the anourous species, the cœliac or common visceral artery arises, as in fishes, which gives off the gastric, the hepatic, the mesenteric, and other arterial branches, to supply most of the chylopoietic organs. The common trunk of the aorta gives off several small vessels to the kidneys and the geni-

tal organs, before bifurcating to form the great iliac arteries, and these two great trunks supply numerous branches to the pelvic organs, before leaving that cavity to ramify on the posterior extremities. The form and distribution of the posterior aorta, however, in the perennibranchiate species, and the urodelous amphibia, more closely resemble the course of that vessel in the coccygeal region of fishes and of the larvæ of anourous species.

The sanguiferous system of *reptiles* is advanced to a higher stage of development than that of the inferior classes of cold-blooded vertebrata, and this superiority is observed chiefly in the magnitude of the pulmonic portion, which accords with the earlier development and the increased extent of their pulmonary organs. The whole heart is proportionately larger and broader, and is situated farther back from the head. The auricles are more muscular, more distinctly separated from each other externally, and are more advanced to the anterior part or base of the ventricle, and the ventricle is more divided internally by an ascending septum, than in the amphibia. The general form of the heart, like that of most other viscera, is modified by the form of the trunk, being more elongated in ophidia, broader in chelonia, and intermediate in the saurian reptiles. The right auricle receives the entire venous blood of the system, and the left auricle, the arterialized blood from the capacious pulmonary sacs; the two divisions of the ventricle give origin to the pulmonary and the systemic arteries, which early communicate with each other by means of two deciduous ductus arteriosi; and the two principal systemic arteries anastamose at a greater or less distance from the heart, to form the common trunk of the descending or abdominal aorta, as in amphibia and fishes.

The two auricles of *ophidian* reptiles are generally much extended in a longitudinal direction, and the ventricle also has an elongated conical form; the auricles are provided with distinct muscular bands, and prominent internal fleshy columns; and the right, which receives the venous blood of the system, is more capacious than the left which receives the arterialized blood from the lungs. The cavity of the ventricle is partially divided by a thick cribriform pervious septum, into a right inferior or pulmonic portion, and a

left superior or systemic portion, which communicate by a wide opening resulting from the deficiency of the septum near the base of the ventricle. The parietes of the systemic portion of the ventricle are thick and strong compared with the small interior cavity, so as to propel the systemic blood through the whole extent of their elongated trunk, and the numerous free fleshy columns which traverse its interior, tend to mingle the venous with the arterialized blood poured into its cavity. The septum of the auricles is thin and diaphanous, and sends from each side of its inner margin, at the base of the ventricle, a crescentic membranous fold, which forms a distinct semilunar valve over each auriculo-ventricular orifice, to prevent the return of the blood during the contraction of the ventricle. The approximated openings of the two systemic aortæ, in the strong upper left compartment of the ventricle, are provided with two semilunar valves, and two similar folds are observed at the opening of the pulmonary artery in the right inferior portion of the ventricle. The right or pulmonic portion of the ventricle is more capacious than the left, and its parietes are less thick, muscular, and cribriform.

The common trunk of the right and left aortæ, on leaving the systemic portion of the ventricle, soon divides to embrace the trachea and œsophagus in the aortic arch, as in other cold-blooded vertebrata; and the two trunks again anastomose a little posteriorly, under the vertebral column, to form the posterior aorta, which extends backwards along the median line of the body to the end of the tail. The right arch of the aorta, in its course upwards and backwards, gives off a considerable thyroid branch, and a large cephalic azygous artery from which the common carotids of both sides originate. The common carotids divide near the head, into a larger external, and a smaller internal carotid artery, and the latter of these branches supplies the place of the vertebrals within the cranium. The right aortic arch also sends off, near its junction with the left, a single median subvertebral artery which extends forwards, and supplies the vertebral or spinal and intercostal arteries to each side of the anterior part of the body. The common cephalic artery in advancing to the head, sends numerous twigs to the œsophagus and the trachea, before it divides to form the common carotids. The

intercostal arteries of the posterior part of the body are derived from the common trunk of the abdominal aorta, formed by the early anastomosis of the left with the right aortic arch, and from the length of the abdominal viscera and their distance from each other, these organs are supplied by distinct hepatic, gastric, mesenteric, and genital arteries, which come off, not from a common cœliac or visceral artery, but successively and directly from the long trunk of the posterior aorta in its course backwards under the vertebral column.

The venous blood is returned from the head by two jugular veins, and from the intercostal spaces by two azygous branches which unite before entering the right auricle. The caudal veins returning the blood from the posterior parts of the body appear to distribute a portion through the kidneys, like the renal portal circulation of fishes, and to convey another portion to the mesenteric vein, to be sent with the venous portal circulation through the liver. The spermatic veins pass with the efferent renal veins into the posterior vena cava, to be sent with the venous blood of the superior cava and hepatic vein into the right auricle and right cavity of the ventricle, and thence by one or two pulmonary arteries through the single or double respiratory sac.

The exterior surface of the ventricle in the *saurians* is more generally connected with the interior of the pericardium by tendinous threads than in the ophidian reptiles; more than twelve of these connecting filaments, most numerous in the invertebrata, are found in the *pseudopus*, two in the monitors, and one or more in the crocodiles and most other genera. I have found eight of these tendinous bands, arising by separate peduncles, near the apex of the ventricle, in the adult heart of the large *gavial* of India, where the pericardium is nearly a line in thickness, white, fibrous, and of great strength. The general structure of the heart and the distribution of the great central blood vessels are nearly the same in the lacertine sauria as in the ophidian reptiles. The pericardium is generally stronger, the auricles more muscular, short, and lobed at the margin, the ventricle with thicker parietes, and the septum more developed between its compartments; the great pulmonic and systemic trunks are bound together by condensed cellular substance and by the

enveloping pericardium, to a greater extent from their origin, before they separate for their respective destinations. The thick parietes of the ventricle are loose, cribriform and deeply cancellated in their interior, from the free and detached condition of the irregular fleshy columns which compose them; and the pulmonic and systemic portions of the blood are mingled together in its cavity, to a variable extent in different species, according to the development and the direction of its imperfect septum. The right and left aortæ, provided with semilunar valves at their origin, commence by distinct orifices in the common cavity at the base of the ventricle, and unite together under the vertebral column after forming a small arch upwards on each side, the left giving off no branches till near the place of its anastomosis with the right, to form the common descending aorta. The two common carotids arise from the arch of the right aorta, and the subclavian arteries come off from the right and left trunks of the aorta at the angle of their reunion. The common trunk of the posterior aorta in passing backwards gives off the intercostals on each side, a branch to the œsephagus and another to the liver. The cœliac and anterior mesenteric originate by a common trunk, which is succeeded by the lumbar, the spermatic, and the posterior mesenteric arteries. From the posterior position of the kidneys the renal arteries come off late, and are succeeded by the two common iliacs, the aortal trunk being here prolonged as a large median sacral artery, corresponding with the magnitude of the caudal prolongation of the body in these lacertine reptiles.

The heart of the *crocodilian* reptiles is enveloped in a very thick and strong pericardium, which also firmly connects together all the great arterial trunks which originate from its cavity. The parietes of the auricles, especially the right, are furnished with strong muscular internal bands, and there are large semilunar valves at each of the auriculo-ventricular orifices. The ventricle has very thick muscular parietes, and its cavity is divided by a strong muscular and columnar septum deeply pitted, which extends from the apex to the base of the heart. The right auricle is much larger than the left, which corresponds with the greater size of the veins and the larger quantity of blood, which enter the former cavity, and the two cavities of the ventricle still communicate with each other

at the base of the heart, as in other reptiles, although here to a smaller extent and during a limited period of life. The venous blood of the system received from the capacious right auricle, appears to be transmitted to the inferior right cavity of the ventricle, which gives origin to the left aortic trunk and also to the common trunk of the pulmonary arteries. These vessels are provided with semilunar valves at their origins, and the pulmonary artery arises from a small fossa of the right ventricle, a little distant from the origin of the left aorta. The osseous lamina observed by Bojanus in the heart of the tortoise, between the origins of the systemic arteries, I have found in the same situation in the adult gavial, where it formed an irregular tuberose morbid growth, and measured about three quarters of an inch in length and two lines in thickness. The arterialized blood from the lungs, received by the small left auricle, and transmitted to the superior, or left cavity of the ventricle, although sparingly, and perhaps for a limited time, sent through the opening of the septum, appears to pass chiefly into the great bulbous trunk, which gives origin to the right arch of the descending aorta, and to the right and left brachio-cephalic arteries or arteriæ innominatæ, which supply the anterior parts of the body. Two semilunar valves are also placed at the origin of this great right systemic artery, in the left division of the ventricle. The aërated blood is thus chiefly sent to the head and arms, by the two ascending trunks from the right aorta, which form the common carotid and the axillary arteries of their respective sides, and also to the legs and tail by the right aortal trunk. The right and left aortic arches, proceeding from distinct orifices of the ventricle, unite together under the vertebral column, as in other reptiles, to form the common trunk of the abdominal aorta, the right arch of the aorta conveying arterialized blood principally to the head, legs and tail, and the left aorta chiefly venous blood to the abdominal viscera.

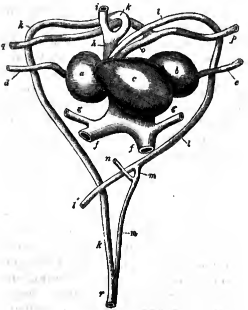
All the three great trunks which originate from the ventricles, the right and left aortæ and the pulmonary artery, form wide and elongated bulbous enlargements at their commencement, and from this bulbous dilatation of the *right* aorta arise the two large trunks, which soon subdivide to form the common carotid and axillary or sub-

clavial artery, on each side. Sometimes the carotids of both sides, arise by a common trunk as in serpents. The subclavian artery gives off an œsophageal, an internal mammary, an inferior cervical and an anterior common intercostal branch, before arriving at the axilla, where it sends off several thoracic branches, and forms the brachial, which divides as usual into the radial and ulnar arteries. The trunk of the right aorta, near its place of union with the left, gives off a considerable posterior common intercostal artery, which is succeeded by two smaller branches, distributed also on the intercostal spaces. The *left* aorta gives off no branches before it arrives near the place of its anastomosis with the right, where it gives off the great cœliac, or visceral artery, which supplies most of the abdominal organs, as the stomach, the liver, the spleen and the pancreas, and leaves only a small and short communicating branch to unite with the right trunk of the aorta. The anterior mesenteric arises from the common trunk of the united aortæ at some distance below the cœliac artery, and is followed by the supra-renal, the renal, and the lumbar arteries, and the profunda femoris, before the aorta gives off the great crural artery on each side to the legs. The posterior mesenteric and the coccygeal arteries arise from the median sacral, which here forms a large prolongation of the aorta, corresponding with the magnitude of this part of the body in the crocodilian reptiles.

The short and broad form of the heart in the *chelonian* reptiles accords with the great transverse development of their body, and with the broad form of the auricle and ventricle already seen in the highest plagiostome fishes, the rays and sharks, which prepares for the division of the ventricle into two distinct cavities in the hot-blooded classes. The entire venous blood of the tortoise is conveyed by the two large inferior and the two smaller superior *venæ cavæ* (Fig. 139. *f. f. g. g.*) into the common sinus venosus, and thence by a single orifice into the capacious right auricle (139. *a.*) of the heart. The smaller left auricle (139. *b.*) receives the arterialized blood from the two pulmonary veins (139. *d. e.*), and both auricles pour their contents simultaneously into the strong muscular and single ventricle (139. *c.*), which propels the blood, by three distinct orifices, into the right (139. *h.*) and left (139. *l.*) aortæ and the

common trunk (139. *o.*) of the two pulmonary arteries (139. *p. q.*)

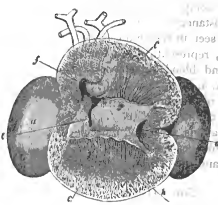
FIG. 139.



Two strong semilunar valves check the return of the venous blood from the right auricle into the sinus venosus, but the same protection is not observed at the single very oblique orifice, by which the two pulmonary veins enter the left auricle. The ventricle is of great size, much extended transversely, depressed in form, with a rounded obtuse apex, with very thick muscular parietes, especially in its left portion, and the innumerable free fleshy columns reduce its interior to a loose reticulate spongy texture. Its exterior surface is generally connected with the pericardium by several tendinous filaments, and the same are sometimes observed passing from the ventricle to the exterior of the auricles. The septum ventriculorum is developed to a variable degree in the species of this order, being least perceptible in the land tortoises, and most distinct in the marine turtles, but is less developed than in the saurian reptiles.

At the base of the ventricle, the two orifices (FIG. 140. *e. d.*) leading from the right and left auricles (140. *a. b.*) are protected by a broad membranous fold (140. *g.*), which extends to the right and left from the septum auricularum, and is strongly connected by tendinous cords (140. *h.*) with the muscular columns of the ventricle (140. *c. c.*). During the contraction of the ventricle,

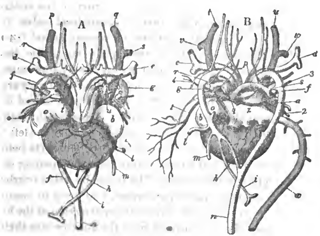
FIG. 140.



the right portion of this broad quadrilateral valve (140. *g.*) appears to direct the current of venous blood (140. *e.*) from the right auricle (140. *a.*) principally along the basilar groove of the right ventricle into the now closely approximated orifice of the bulbous commencement of the pulmonary artery, and probably, also the left aorta; and the arterialized blood (140, *d.*) from the left auricle (140. *b.*) is carried through the spongy columnar parietes towards the right side of the left ventricle and the right aorta, the orifice of the left aorta being a little nearer to the pulmonary artery than the opening of the common right systemic trunk. The muscular valve overhanging the orifice of the pulmonary artery, may tend to complete the septum of the ventricles during the contraction of the heart, and thus direct the two currents from the auricles into their respective arterial trunks, as supposed by Meckel. Besides the broad valvular extension from the septum of the auricles, each auriculo-ventricular orifice is provided with another distinct and opposite semilunar fold, most developed on the right, to complete its protection, and a large muscular fold (140. *f.*) is seen to overhang the pulmonary artery in the right cavity of the ventricle, extended from the septum ventriculorum, and supported by cordæ tendiniæ, like the muscular tricuspid valve in the right ventricle of birds.

The three great arterial trunks which arise by distinct orifices from a fossa on the right side of the base of the ventricle, are provided each with a pair of semilunar valves at their origin, and are compactly united together for a short distance by cellular substance and pericardium on leaving the cavity of the heart, as seen in the annexed figure (FIG. 141. A. B.) from Bojanus, representing the ventral and dorsal aspect of the heart and blood vessels of *testudo europæa.* The elongated right (A. *a.* B. *a.*) and left (A. *b.* B. *b.*) auricles rest on the broad base of the ventricle (A. *c.* B. *c.*), and the great arterial systemic trunks (A. *d. e. f. g.*) soon separate for their several destinations. A strong muscular band (A. *v.*) with circular fibres, embraces the origin of the great arterial trunks (A. *d. e. f. g.*), and the trunks of the coronary arteries

FIG. 141.



and veins wind round the same part of the ventricle (A. *c.*), extending their ramifications towards the posterior margins and the apex. The right systemic artery, after giving off the right arch (A. *f. f.* B. *f.*) of the descending aorta (A. B. *n. n.*), advances a little forwards, and divides into the right and left arteriæ innominatæ, each of which again bifurcates to form a small ascending common carotid and a large subclavian artery (A. B. *d. e.*) The common carotid, on each side, supplies the parts of the neck, and is continued, ramifying like

the external carotid of mammalia, over the head and face, the internal carotid artery being here a very small branch to the small contents of the cranial cavity, and, as in other reptiles, the vertebral artery is not required to enter the small cranium. The subclavian artery (A. B. *d. e.*), on each side, also gives off several branches to the neck, and to the scapular and pectoral muscles, the two anterior intercostal arteries, and the internal mammary which, in passing backwards along the interior of the ribs, anastamoses with the intercostals and with the epigastric artery. A few branches to the dorsal and scapular muscles are given off from the axillary artery in its passage to the inner part of the head of the humerus, where, as brachial artery, it sends off the usual deep and circumflex branches, and on arriving at the elbow-joint, it divides into a small radial and ulnar artery to supply the short fore-arm and hand.

The right aorta (A. *f.* B. *f.*), after leaving the common systemic trunk of that side, passes upwards and backwards to unite with the left aorta (A. *g. h.* B. *g. h.*) under the vertebral column, and sends off, in this course, one or more intercostal branches. The right and left aortæ unite with the right and left branches of the pulmonary artery (B. *p. q.*) by means of two *ductus arteriosi* (B. *r. s.*), which remain, with their canal obliterated, in the adult state. The left aorta (B. *g.*), arising by a distinct orifice from the left portion of the ventricle, follows a course analogous to the right, without sending off branches to the anterior part of the body, and is appropriated almost entirely to the abdominal viscera, a small communicating branch (B. *h.*) being alone left to anastomose with the right aorta. From the left arch of the aorta arise three visceral arteries, the gastric or coronary artery (B. *l.*) to the œsophagus and the stomach, the cœliac (B. *m.*) which sends branches to the liver, the pancreas, the spleen, and the large intestines, and the mesenteric artery (B. *i.*), which is chiefly spread on the mesentery and small intestines. The common trunk of the abdominal aorta (A. B. *n. n.*), in passing backwards, gives off a few posterior intercostal branches, the two spermatic arteries, several renal branches to the lobulated kidneys, some small lumbar arteries, and a cloacal branch like a posterior mesenteric, and after sending out the large iliac arteries on

each side, it is continued along the sacrum and coccyx as a small median caudal artery, as in other reptiles. The internal iliac ramifies mostly on the urinary bladder and other pelvic viscera, and the external iliac, after giving off the epigastric and circumflex arteries, and continuing to afford numerous branches to the thigh and leg as crurial and anterior tibial artery, terminates in a dorsal arch, extending outwards over the tarsus, from which the digital arteries of the foot are derived.

The venous blood returned from the head and neck by the jugular veins (B. *t. u.*) in the chelonia, as in other reptiles, and that brought from the arms by the subclavian veins (B. *v. w.*), is conveyed by the right and left anterior or superior venæ cavæ (139. *g. g.*), formed by the union of these two veins on each side, into the common sinus venosus (141. B. *z.*), which receives the blood from the abdominal veins. The abdominal veins receive the blood from the posterior parts of the body, and from the renal and hepatic portal systems, and, after communicating on each side with the jugular veins by an anastomosing branch, they enter the sinus venosus, which pours its contents by a single broad valved orifice into the right auricle of the heart (A. *a.*) The two pulmonary arteries (B. *p. q.*) arise by a lengthened single bulbous sinus from the left inferior part of the right ventricle, and, after communicating by the ductus arteriosi (B. *r. s.*) with the two aortæ (B. *f. g.*), they follow the ramifications of the bronchi through the extensive cavities of the lungs. The two small returning pulmonary veins (B. 1. 2.) unite to form a small sinus before entering by a single opening into the left auricle. The veins of reptiles, like their chyliferous and lymphatic vessels, are provided with scanty and ineffective valves, which allow injections to pass readily against their course, from trunks to branches.

In the class of *birds*, the septum of the ventricles is at length completed, and the pulmonic circulation is entirely distinct from the systemic, as in all the hot-blooded vertebrata. The air admitted into contact with the systemic capillaries in the interior of the bones and in the large air-cells extending through most parts of the body, oxygenates and decarbonizes a larger portion of their blood, and is the source of their high temperature, their great muscular force, and the encreased energy of all their functions. By their

habitual great muscular exertions, the blood is determined from the deep-seated to the superficial parts, by which their surface-temperature is elevated for incubation, their down and plumage are developed to equalize their temperature or to aid their flight, and their perspiration is increased to moderate their occasional heats.

The heart of birds, of a tapering conical form, with thick muscular parietes, is placed longitudinally on the median plain, anterior to the liver, enclosed in a thin transparent vascular pericardium, surrounded by air-cells prolonged from the bronchi, and still occupies, as in the inferior vertebrata, a more advanced position in the trunk than in the mammiferous tribes. The right auricle and ventricle, especially in diving birds, have more capacious cavities with thinner parietes, than the corresponding parts on the left side, and the venous blood of the system is received into the right auricle from the two anterior and the larger single posterior, venæ cavæ, by three distinct orifices provided with strong semilunar valves to direct the currents and check regurgitation. The thin muscular outer parietes of the capacious right ventricle envelope the greater part of the exterior of the strong left muscular cavity, and the right auriculo-ventricular orifice is here defended by a thick fleshy valvular fold extended from the base of the ventricle, which probably aids in forcing the blood through the fixed lungs of birds, where the diaphragm is almost wanting. The arterialized blood arrives from two pulmonary veins by a single orifice in the left auricle, which is provided, like those of the superior venæ cavæ, with only one semilunar valve, and the walls of this auricle are more muscular and columnar than the smooth parietes of the right cavity, but neither of these cavities yet presents auricular appendices developed from its margins, as in mammalia. The left auriculo-ventricular orifice is protected, as in quadrupeds, by a membranous mitral valve, composed of two folds, and connected by its irregular free margin, with the thick fleshy columns of the ventricle, by means of numerous tendinous cords.

The arterial orifices of the right and left ventricles of birds are single, and provided with three semilunar valves, as in all the higher vertebrata, and all the parts of the heart, though completely separated internally by the inter-auricular and inter-ventricular septa, are now more intimately united

together externally, and more compactly adjusted to each other's form, than in the inferior classes. From the shortness of the trunk in this class, and the proximity of the heart to its anterior part, the single great systemic artery proceeding from the base of the thick conical left ventricle, early divides into three principal trunks as it proceeds to the right side of the body, along which the single abdominal aorta descends to the pelvic region. As the arch of the aorta is here directed to the right side, the first branch given off is the left arteria innominata, which is the common trunk of the carotid, the subclavian, the vertebral, and the thoracic arteries of that side. The second branch of the aorta is the arteria innominata of the right side, which divides in a manner similar to that of the left. The third branch is the great trunk of the descending or abdominal aorta which supplies the viscera and posterior parts, and varies less in its magnitude than the two anterior aortic branches, which are greatly developed in birds with large wings and powerful flight, and very small in strutheous birds with heavy body and feeble wings. The arteria innominata or great brachiocephalic trunk, on each side, sends forward the common carotid artery which, after giving a branch to the œsophagus and crop, generally gives origin to the vertebral artery. The common carotids mounting along the fore part of the neck, beneath the muscles, are most generally found both on the left side, or with the right carotid extending along the median plain, and near to the head they commonly divide into the external and internal carotids, the internal being here, as in the lower vertebrata, only a small branch of the external trunk of the artery. Many birds have only the left carotid, and a few only the right carotid artery developed from the subclavian, and then dividing into two. The principal branches of the external carotids are the superior thyroid, the lingual, the occipital which receives the anastomosing end of the vertebral, the large facial which forms the facial plexus behind the orbit, and the palatine which often unites with the opposite, like the lingual, to form a median trunk. The exterior branch of the internal carotid artery forms the ophthalmic, and gives off an occipital, an inferior palpebral, an ethmoidal, a lachrymal, and sometimes an inferior maxillary, a harderian, a nasal,

and a frontal branch, and terminates in the ciliary arteries which ramify minutely on the choroid membrane. The interior branch of the internal carotid is chiefly occupied in forming the cerebral arteries, and its terminal branches entering the orbit, anastomose with the divisions of the ophthalmic artery. The vertebral artery ascends, with the cervical portion of the sympathetic nerves, through the foramina of the transverse processes of the cervical vertebræ, sending off small branches to the surrounding parts in its course upwards to the atlas, where it anastomoses with the occipital artery, and sends in a minute twig to the medulla oblongata, so that the basilar artery is here formed by communicating branches of the internal carotids; the blood of the vertebral arteries is diverted from the internal to the external parts of the head, as in the reptiles and the lower herbivorous mammalia.

The great brachio-cephalic artery on each side, after giving off the common carotid and vertebral, becomes the subclavian and sends off an inferior thyroid to the lower larynx, an internal mammary, and large thoracic and scapular arteries to the surrounding muscular and cutaneous parts, especially to the great pectoral muscles so important in flight, and to the highly vascular subcutaneous incubating organ spread over the abdomen. From the magnitude of the branches thus sent from the subclavian, and from the smallness of the muscular parts of the arm of birds, the axillary artery is here greatly reduced, and after giving off the circumflex and deep-seated branches, the brachial artery proceeds as usual along the inner side of the humerus, and divides near the elbow-joint into a small radial, and a larger ulnar artery which furnishes considerable branches to the inter-osseous space and the rest of the fore-arm, and distributes its terminal twigs on the three fingers of the hand, and on the cutaneous parts of the development and growth of the large feathers of the wing.

The third or right branch of the great systemic artery issuing from the left ventricle, is the principal continuation of the trunk, forming the descending or abdominal aorta, which arches upwards and backwards on the right side of the vertebral column, over the right bronchus, and gradually acquires a median position under the bodies of the vertebræ, along which it proceeds to the end of the

coccyx. The descending aorta in passing backwards, sends out considerable œsophageal and bronchial arteries, a variable number of intercostal trunks, and numerous smaller dorsal and lumbar branches to the parts around the spine. The cœiiac artery is here a considerable trunk, which is devoted chiefly to the alimentary canal and the gastric cavities, the branches being small which proceed to the chylopoietic glands. This great cœliac trunk sends a branch forwards to the œsophagus, another the gastric to the ventriculus succenturiatus and the gizzard, and much smaller branches to the spleen, the liver, and the pancras, and where the cœca-coli are of considerable size they also receive a separate branch from the same trunk. The chief continuation of the cœliac artery, after giving off small branches to the œsophagus the spleen and the liver, generally divides into a right and a left gastric artery which spread on the corresponding sides of the gizzard, the right sending out a branch to the duodenum and pancreas, and another to the intestinum ilium and cœca-coli, and the left giving branches chiefly to the ventriculus succenturiatus and the left lobe of the liver.

From the high origin of the external iliac or crurel arteries in birds, only one mesenteric, the superior mesenteric artery, arises from the trunk of the aorta, above the commencement of these vessels, as in the class of reptiles. This vessel arises a little below the cœliac, from the fore part of the aorta, and spreads its ramifications over most parts of the mesentery, the intestinal canal and the cœca-coli, anastomosing anteriorly with branches of the gastric arteries, and posteriorly, on the rectum, with branches of the small posterior mesenteric which arises from the median sacral artery. Below the superior mesenteric, the common trunk of the right and left genital or spermatic arteries arises from the fore part of the aorta, and each of these arteries sends a branch to the upper large lobe of the kidney, and another to the testicle or to the ovary and oviduct, of its respective side, these genital branches having a tortuous course, and being subject to periodical enlargements with the genital organs, as in other animals. The right and left *profundæ femoris* or deep-seated femoral arteries have separate origins from the sides of the aorta in birds, and distribute their branches to the muscular parts of the abdomen and femur as far as the

knee, the epigastric arteries being derived from these deep femoral trunks on their escaping from the pelvis. After the giving off of the great external iliac or crural arteries, which, from their relative size, are almost bifurcations of the aortal trunk, the median sacral artery sends out a few lumbar branches to the surrounding parts, a small inferior mesenteric to the rectum and colon, and two minute internal iliacs to the urinary and genital organs, and terminates at the end of the coccyx by ramifying on the muscular and cutaneous parts which it supports.

The external iliac or crural arteries, before leaving the pelvis, send off some minute renal branches to the small inferior lobes of the kidneys, and on leaving that cavity to become the femorals, they distribute the circumflex and other branches to the muscles of the pelvis and thighs. As popliteal artery it gives articular branches to the parts around the knee-joint, and divides behind into the anterior and posterior tibial arteries, the posterior sending out a considerable peroneal or fibular branch, which descends along the fibula to form articular branches around the heel. The course of the anterior tibial artery is often marked, in aquatic birds, by an enveloping plexus of its smaller anastomosing branches, which surround the trunk of the vessel, and reunite to it at the heel-joint, resembling in form and use the brachial and crural plexuses of tardigrade mammalia. The prolonged trunk perforates the lower end of the metatarsal bone, to gain the sole of the foot as plantar artery, where some of its branches extend to the extremities of the toes, and others ascending behind the metatarsus, anastomose freely with the descending twigs of the fibular artery. There is thus a nearer approach to the mammiferous type in the distribution of the arterial trunks, as well as in the structure of the heart of birds, than is met with in the inferior vertebrata, but notwithstanding the remarkable unity of organization in this class, the diversities observed in the distribution of the arteries in different species of birds, is almost as great as in the diversified forms of quadrupeds.

The venous blood is returned from the feet and legs of birds by the deep-seated fibular and tibial veins which unite to form the femoral trunk, and this uniting with the ischiadic from the muscular parts around the pelvis, forms the prin-

cipal trunk of the iliac vein on each side, the course of the superficial veins on the legs and arms imitating in some degree their distribution in quadrupeds. After receiving the hæmorrhoidal, the emulgent, the caudal, the hypogastric, the spermatic, and other veins of the pelvis, the two iliacs unite to form the inferior cava, which in advancing to the heart, receives the trunks of numerous distinct hepatic veins which emanate from behind the liver, and the inferior cava forms the same capacious sinus in diving birds as in other diving animals. The smaller branches of the inferior cava anastomose freely with the mesenteric veins proceeding to form the vena portæ of the liver, and others, advancing from the posterior part of the pelvis, form two trunks which penetrate the kidneys, and appear to form a renal portal circulation to contribute to the secretion of these organs. The principal part of the venous blood however, from the chylopoietic organs, from the spleen, the pancreas, the stomach and intestines, is collected into the great trunk of the portal vein, to be transmitted with the blood of the hephatic artery, through the lobes of the liver, and by the free communications of these two portal systems, the renal and the hephatic, they are capable of relieving each other, as well as the inferior cava, the sinus venosus, and the heart.

The venous blood is returned from the hand and fore-arm chiefly by two veins, which unite at the bend of the arm to form the humeral vein, and these vessels accompany the corresponding arteries, but in a more superficial position. The axillary or subclavian vein on each side, after receiving the superficial and deep-seated branches around the shoulder and fore part of the trunk, unites with the jugular and vertebral vein to form the superior vena cava of its respective side. The vertebral vein of each side anastomoses freely at the exterior of the base of the skull with the branches of the single jugular vein, and accompanies the vertebral artery and cervical portion of the sympathetic, through the canal of the transverse processes, receiving the blood from the sinuses of the brain, the cervical portion of the spinal chord, and the back parts of the neck. The jugular veins are single on each side, and anastomose freely with each other, as well as with the vertebral veins, below the base of the skull, so that a free circulation is provided for under the various circumstances

of external pressure to which the head and neck of birds are exposed. They receive the blood chiefly from the external parts of the head, and the œsophagus, crop, and other parts of the neck, and, passing down superficially, along with the pneumo-gastric nerve, they unite with the subclavian and vertebral vein on each side, to form the right and left superior venæ cavæ, as in the inferior vertebrata and most of the lower mammalia.

The venous blood thus conveyed to the right auricle by the single inferior and the two superior venæ cavæ, is sent by the right ventricle into the pulmonary artery, provided at its orifice with three semilunar valves, like the aorta, which immediately divides into a right and left branch, to ramify through the corresponding lungs. The two pulmonary veins return the arterialized blood to the left auricle of the heart by a single orifice, which is partially protected by a semilunar valve. The pulmonary arteries of birds communicate at an early period with the aorta, by means of the posterior pair of branchial arches, forming a ductus arteriosus on each side, as in the lower pulmonated vertebrata, and the latest of these ductus arteriosi to become obliterated, is the one upon the left side, which also remains alone to a late period in the fœtal condition of mammalia. The two brachio-cephalic arteries result from the metamorphosis of the anterior branchial or aortic arches of the embryo, the descending aorta from that of the middle arch of the left side, and the pulmonary arteries, as usual, from the posterior aortic arch. So that the peculiarities in the structure of the heart of birds, and in the course of their sanguiferous vessels, are alike affinities to the lower reptiles and to the inferior tribes of mammalia, and the metamorphosis of their branchial arches is in accordance with that of all the other pulmonated vertebrata.

The same plan of structure observed in the vascular system of the lower vertebrata, has arrived at its maximum of development in the *mammiferous animals*, especially in the higher quadrupeds and in man, but numerous modifications of this complex hydraulic apparatus are necessarily presented in this varied and extensive class, depending on differences in the structure and condition of internal parts, or in the general outward form of the body, or connected with peculiarities in the living habits of species. The right and left

cavities of the heart are always separated, at maturity, hy impervious septa; the descending aorta is formed by the right arch, and not by the left as in birds; the thick muscular fold of the right ventricle of inferior vertehrata is here, with few exceptions, as the ornithorhyncus, supplied by a more delicate and complicated membranous tricuspid valve; the fibrous and serous coats of the vessels are more distinct; the valvular apparatus throughout the sanguiferous system is more perfect and effective, and the valves of the veins more numerous than in the inferior classes; the whole heart is proportionately larger, and situate more posteriorly in the trunk. The depressed and flattened form of the heart, common in the chondropterygious fishes and chelonian reptiles, is seen in the lowest mammalia, as in many of the edentulous, the pachydermatous, and the cetaceous animals, where we observe also in the adult condition of the herbivorous lamantins, the rytinæ, and the dugongs, the primitive cleft or detached form of the two ventricles, throughout half their extent from the apex towards the base, as in the embryo state of this organ in higher animals and in man. This retention of the earlier bifid condition of the apex of the heart, resulting from the drawing up of the septum in dividing the original single ventricular cavity into two, which is seen also in the porpoise and slightly in the seal, is in accordance with the general inferiority marked in the other systems of these lower aquatic mammalia.

The first portions of the two great arterial trunks, near their origins from the heart, are sometimes found enlarged in cetacea, like the bulbi arteriosi of inferior classes; and in the diving amphibious mammalia, as the seals, besides the usual dilated inferior vena cava or sinus venosus common in most aquatic vertehrata, to allow of their prolonged submersion and suspended respiration, we often find the foramen ovale, the ductus arteriosus, and the ductus venosus, remaining to the adult state, quite pervious as in the earlier fœtus of higher tribes. The parietes of the ventricles are thicker in mammalia than in lower classes, the right ventricle is less extended around the left than in birds, and the interior surface of these cavities is more even, and presents fewer detached muscular chords, than in reptiles. In the lower orders of mammalia the heart is generally more median in

its position, extending along the middle of the sternum, and more longitudinal in its direction, with the apex at a variable distance from the diaphragm, than in the higher quadrupeds and man, where it is directed more transversely, inclines to the ribs of the left side with its apex, and rests with its pericardium contiguous to the diaphragm. The right ventricle being shorter and broader than the left, the superficial groove of separation between them lies to the right side of the apex, and marks the direction of the coronary arteries, which arise from the commencement of the aorta; the coronary veins terminate by a valved orifice directly in the right auricle, which generally presents a distinct muscular auricular appendix, a permanent fossa ovalis, and a remnant, more or less distinct, of the Eustachian valve so important in the fœtus. The nerves of the heart are derived from the great sympathetic and the pneumogastric, as in other classes. The entire heart is more oblique in its position, with its posterior surface more approximated to the diaphragm, and the pericardium is more intimately connected by cellular substance to the middle tendinous part of that muscle, in man and the higher quadrumana, than in the inferior quadrupeds where the lower vena cava is consequently longer. It is also sinistral in its direction in the mole, from the size of the right lung. It is also in man and the quadrumana that we find the Eustachian valve most developed, and in several rodentia. The muscular parietes of the right ventricle appear proportionately thicker in the porpoise and other cetacea, than in terrestrial quadrupeds. In the right ventricle of the ornithorhynchus, the tricuspid valve is muscular, like that of a bird. The semilunar valves, at the origins of the aorta and pulmonary artery, are three in number, as in birds, and are provided with the same prominent corpuscula Aurantii in the middle of their free margin, and here also the coronary arteries, to supply the heart, commence in the fossæ behind these valves. In the heart of many of the adult ruminating and pachydermatous quadrupeds, one or two considerable cruciform osseous laminæ are almost constantly found at the base of the septum ventriculorum, between the origins of the great arteries from the ventricles, as seen also in the adult saurian and chelonian reptiles.

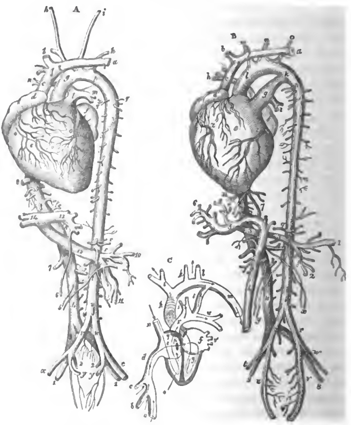
In the mammalia as in birds, there are most generally

but two branches sent from the arch of the aorta, for the nourishment of the anterior parts of the body, and this structure has been observed among species the most dissimilar of nearly all the orders of this class. In some of the cetacea, pachyderma, and edentata, and in most of the rodentia, masupialia, and carnivora, the first trunk from the arch of the aorta is the great brachio-cephalic or *innominata* which gives off the right subclavian and the two common carotids, and the second or left trunk from the aortic arch is the left subclavian, which arises separately as in man. In some of the cheiroptera and insectivora, as *vespertilio* and *talpa*, the two aortic trunks consist, as in most of the feathered tribes, of two similar brachio-cephalic arteries which divide each into a subclavian and a common carotid. In the lowest herbivorous quadrupeds, the ruminantia and the allied solid-ungulous pachyderma, one trunk only arises from the arch of the aorta as in the chelonian reptiles, but this single great brachio-cephalic trunk here divides into two unequal branches, the larger on the right side giving off the right subclavian and the united trunk of both common carotid arteries, and the smaller branch being the subclavian artery of the left side. In the elephant, however, the right as well as the left subclavian has a separate origin, making thus three branches from the arch of the aorta, the middle one of which is the united trunk of the two common carotid arteries.

In the higher quadrumana and in man, as seen in the annexed figure (142) of the adult and fœtal human vascular trunks, there are three branches from the arch of the aorta, for the anterior parts of the body, the first being the right brachio-cephalic or arteria innominata (142. A. *g. h.*) which divides into the subclavian and common carotid of the right side, the second forming the left common carotid (142. A. *i.*), and the third branch being the subclavian (142. A. *k.*) of the left side. The same structure is seen in some insectivorous and carnivorous quadrupeds, as the hedgehog and seal, and in some of the lower orders of mammalia, as in the beaver, the hamster, the rat, the sloth, the armadillo, the ant-eater, and the ornithorynchus; and most of the other normal forms of these aortic trunks met with in inferior tribes, occasionally present themselves as abnormal varieties in the human body. So that the arterial trunks which most generally come off

directly or separately from the arch of the aorta, are those of the left side, the left subclavian and the left carotid, as might be inferred from their greater distance from the heart, the prime mover of the circulation.

FIG. 142.



There is great uniformity in the distribution of these aortic trunks in man and the inferior mammalia, as in the structure of the organs which they supply. The common carotid (142. A. *k. i.*) on each side divides, at the side of the larynx, into an *external* and an *internal* carotid artery, without giving any branch from the common trunk. The external

carotid commonly gives off, a *superior thyroid* to the thyroid gland and larynx, a *lingual* branch to the tongue, a *facial* or external maxillary extensively ramified on the external and internal parts of the face, an *inferior thyroid* which, however, in the short neck of man, is derived from the subclavian, a small *ascending pharyngeal* to the pharynx and adjoining parts, an *occipital* to the posterior parts of the head and neck, a *posterior auricular* chiefly to the external and internal parts of the ear, a large *temporal* to the exterior lateral parts of the head, and a larger *internal maxillary* artery extensively distributed on the deep-seated parts of the face, the teeth of the upper and lower jaws, and the lining membrane of cranium. In the long necks of ruminating quadrupeds the inferior thyroid artery is restricted to the thyroid gland, and the superior thyroid to the larynx, and in the myrmecophaga tridactyla both right and left superior thyroid and the left inferior thyroid, have their place supplied by a single branch from the trunk of the right brachiocephalic artery, which is ramified on the thyroid gland and the larynx.

The *internal carotid* artery passes in a tortuous manner to the foramen caroticum, by which it enters the cranium to be distributed chiefly on the anterior and middle parts of the brain, the posterior parts being supplied by the vertebral artery, and the membranes by the meningeal branches from the external carotid; so that the *internal carotid* varies much in its relative size according to that of the anterior parts of the brain, being a small branch in the inferior mammalia, as in the lower classes of vertebrata, and a large division of the common carotid in the higher carnivora, quadrumana, and man. The *internal carotids* of the ruminantia, on arriving at the sides of the sella turcica, subdivide into innumerable minute anastomosing twigs, forming a *rete mirabile*, and these twigs again unite to recompose the arterial trunks, before they are distributed on the pia mater to penetrate the delicate texture of the brain. This structure resembles that of the plexuses of the brachial and femoral arteries in tardigrade quadrupeds, and serves the same function in retarding the impetus of the blood in the long pendent neck of these animals, before entering the brain. The same structure is found also in some of the more powerful carnivora, and in a

few other quadrupeds, whose living habits necessitate this protection, and whose cerebral blood is chiefly derived from the internal carotid. In the erect bodies of man and the higher quadrumana it is not developed, nor is it required in the small *internal carotids* of the rodentia, where these vessels are often less than the *vertebral arteries*, nor in the plantigrade carnivora. On traversing the carotid canal of the temporal bone, and the cavernous sinus of the dura mater, the *internal carotid* artery, on each side, sends forwards an *ophthalmic* branch to pass, with the optic nerve, through the foramen opticum, to the organ of vision and the surrounding parts. It sends backwards a *posterior communicating* branch to unite with the *posterior cerebral* branch of the *basilar*, and, advancing forwards, it gives off the *anterior cerebral* which anastomoses with its opposite, by a very short *anterior communicating* branch, before turning upwards to ramify on the cerebral convolutions above the corpus callosum. The *internal carotid* sends outwards likewise a *middle cerebral* artery, along the fissure of Sylvius, to be distributed chiefly on the anterior and middle parts of the brain. The numerous windings, anastomoses, and subdivisions of the *internal carotid* or *cerebral arteries* on the pia mater of mammalia, and the more complicated *retia mirabilia*, serve to prepare these nutritious vessels, for penetrating in safety the delicate texture of the brain, as the nutritious arteries of bone subdivide on its periostium.

The *subclavian artery* on each side (142. A. *b. k.*) is chiefly appropriated to the atlantal extremities, and varies in its size and distribution according to the development and form of these members; it sends also branches to the head and anterior parts of the trunk, as the *vertebral*, the *superior intercostal*, the *internal mammary*, several *scapular* and *cervical* arteries, and, in man, the *inferior thyroid* which in other mammalia comes from the external carotid. The *vertebral arteries* ascend to the foramen occipitale, through the foramina in the transverse processes of the cervical vertebræ, giving off branches to the spinal chord and the dura mater; and, after winding round the articular processes of the atlas, and entering the occipital foramen, they unite below the medulla oblongata, to compose the trunk of the

basilar artery, which is distributed chiefly in the cerebellum and posterior parts of the brain. In the bradypus tridactylus the *vertebral artery* enters the foramen of the eighth vertebra from the occiput, in most mammalia it enters that of the seventh, and in man and many other species it enters that of the sixth or the fifth cervical vertebræ. Instead of a rete mirabile, it assumes a tortuous course, like the *internal carotid*, before entering the cranium. The *vertebral artery* is often as large as the internal carotid, as in the guinea-pig and the agouti, where the latter artery is only a small branch of the internal maxillary, and where the *circle of Willis* is formed principally by the branches of the large *basilar* artery. In some other species, as the marmot and the porcupine, the *vertebral arteries* exceed in magnitude the internal carotids. In the hybernating cheiroptera, which generally hang suspended by the feet with their head downwards, and where there is no protecting *rete mirabile* on the internal carotid, the cerebral blood is chiefly conveyed through the large vertebral arteries. In the ruminantia, as in birds, the *vertebral arteries* are distributed principally on the exterior, and not the internal, parts of the head, these vessels anastomosing more or less extensively with the *occipital* branches of the *external carotids*, and not passing inwards to form the *basilar artery:* so that these quadrupeds, with their small internal carotids, have generally the exterior parts of their head greatly developed, at the expense of the more important intellectual organs. The great size of the cerebellum of rodentia, and the imperfect development of their smooth bird-like cerebral hemispheres, appear also to be connected with the magnitude of their *vertebral arteries* and the minuteness of their internal carotid or *cerebral arteries.*

The *superior intercostals* supply the anterior intercostal spaces; the *internal mammaries* send branches to the diaphragm, the mediastinum, the pericardium, and to the mammary glands when pectoral, and also branches to anastomose with the *epigastrics* from the *external iliacs;* the *scapular* and *cervical* arteries chiefly supply the muscles of the shoulder and neck. The great trunk of the *subclavian* continues its course as *axillary* and *brachial* artery, sending off numerous *thoracic* and *circumflex* branches to the mus-

cular and deep-seated parts around the shoulder joint, and branches to the parts along the humerus, at the lower part of which it divides into the *radial* and *ulnar* arteries to supply the fore-arm and hand, as in the inferior classes and in man. The *ulnar artery* generally sends off, near its origin, a considerable *interosseous* branch to supply the anterior and posterior parts of the interosseous space. The *radial* and *ulnar* arteries, after giving off several important branches in their course to the wrist, form a *deep-seated* and a *superficial palmar arch*, which anastomose with each other, and supply arteries to the hand, and *collateral* branches to the sides of the fingers according to their number in the different mammalia, like the *plantar arches* of the posterior extremities.

The bifurcation of the *brachial artery* in the short arm of the cetacea, and in the ornithorhynchus, the marsupialia, and several quadrumana, takes place much higher than in man, and in the ruminantia, the solidungula, and some of the rodentia, as the marmot, much lower on the fore-arm. In the walrus, the *brachial* continues undivided to the metacarpus. In most carnivora, and many rodentia, edentata, monotrema, marsupialia, insectivora, and quadrumana, animals with free prehensile use of their arms, the *brachial* artery, sometimes the *ulnar,* passes palmad through the osseous canal above the inner condyle of the humerus, accompanied by the median nerve, to protect them from pressure. But in the tardigrade mammalia with a plexiform humeral artery, the vessel is not protected by an osseous canal, and in the myrmecophagæ, where this epitrochlear canal is present, it transmits only the median nerve, while the plexiform brachial artery passes free over the inner margin of the humerus. The *radial* and *ulnar* arteries are equally present, where the ulna is only rudimentary or wanting; but in the seal and walrus the brachial artery continues to the wrist, and supplies their place. The hand of solidungula is supplied with *collateral* branches as one finger, and that of ruminantia as two ; but the vessels are less regular in the rudimentary fingers. In the tardigrade sloths and loris, the *brachial* and *femoral* arteries give off at their origins, several trunks which subdivide into numerous anastomosing plexiform branches, and which follow them in their course enveloping the primary trunks and sending twigs to the muscles

and at length reunite with them to compose the usual trunks which give off the arteries of the fore-arm and leg. This plexiform structure exists also in the extremities and tail of the ant-eaters, in the long legs of the tarsius, in the arms of the porpoise and the lamantine, and perhaps in many other mammalia, and it resembles the *rete mirabile* of the *internal carotids* in other tribes, where the plexiform branches however, reunite to compose the trunks of the cerebral arteries. In the two-toed ant-eater, the arterial plexus envelopes the commencement of the radial and ulnar arteries, as well as the trunk of the brachial; but in the lamantin, and also in the porpoise, the trunks of these arteries are entirely subdivided into fasciculi of minute vessels, and even the branches which they appear to give off, are only smaller fasciculi of the same minute plexiform arteries. This structure appears to be general in the arms of cetacea, and is probably connected with the limited mobility of these members, as supposed by Bear; the plexiform condition of the arterial trunks is seen also in the legs of many birds.

As the parts supplied by the descending aorta are more uniform in their character, than those nourished by the ascending branches, the arteries of the trunk are more constant and less modified than those of the extremities in the different tribes of mammalia, and vary little from the arrangement presented by these vessels in the human body. In the thorax, the descending aorta (142. A. *q. q.*) commonly gives off two or more *bronchial* arteries, to accompany the ramifications of the bronchi, and nourish the lungs; several small *œsophageal* branches, to that part of the alimentary canal; minute *posterior mediastinal* arteries, to the pericardium; and a variable number of symmetrical pairs of *intercostals* (142. A. *q. r.*), chiefly to the muscular parts of the thorax. In many of the cetacea are observed numerous azygous intercostal arteries, arising from the posterior and median part of the thoracic aorta, which form a compact mass of arterial plexuses, lining the whole dorsal part of the chest, surrounding the vertebral column, penetrating the vertebral canal, enveloping the spinal chord, and even extending to the interior of the cranium. They are enveloped in a loose elastic cellular tissue, accompanied with corresponding plexuses of veins, and have been supposed connected with the

secretion of the large external deposit of adipose substance, or destined to preserve the high temperature of the nervous axis and other internal organs.

On passing into the abdomen, between the crura of the diaphragm, the *aorta* gives off from its sides, the two small *phrenic* arteries (142. A. above *r.*) to the diaphragm; two or more minute *supra-renals* to the supra-renal capsules; the two *renal* arteries to the kidneys; a pair of *spermatic* arteries (142. A. *t.*), to the testicles, or to their analogues the ovaries, according to the sex; and a variable number of symmetrical pairs of *lumbar* arteries, destined to supply the exterior parietes of the abdomen, like the intercostals of the thorax. The largest and most important trunks, however, arise from the anterior median part of the *abdominal aorta*, and are the *cœliac* (142. A. *r.*) which sends off the *coronary* to the stomach, the *hepatic* to the liver, and the *splenic* to the spleen; the *superior mesenteric* (142. A. *s.*), which arises near the cœliac, and supplies the small intestine and part of the colon, and the small *inferior mesenteric* (142. A. *u.*), which arises near the commencement of the iliac arteries, and is distributed on the colon and rectum. The direct pelvic continuation of the abdominal aorta is the caudal or *median sacral* artery (142. A. between *v. w.*), which, in man, and in other tail-less and long-legged mammalia, forms but a small branch compared with the two *iliacs* (142. A. *v. w.*), which appear to constitute a bifurcation of the entire trunk; but in the cetacea, and other long-tailed species, the proportions are very different. In man and a few of the higher quadrupeds, the *aorta* gives off two large *common iliac* arteries (142. A. *v. w.*), each of which divides into an *internal iliac* (142. A. *y. y.*) appropriated to the viscera of the pelvis, and a larger *external iliac* (142. A. *x. x.*) to supply the leg; but in most of the lower mammalia, as in ruminantia, rodentia, marsupialia, carnivora, and other orders, the *internal iliac* arteries arise separately from the prolonged trunk of the *aorta* behind the *external iliacs*. From the want of legs in the cetacea, they have no external iliacs.

The *internal iliac* artery of each side furnishes the *ilio-lumbar* branch, to the muscles of that region; the *obturator*, chiefly to the ilio-femoral joint and the adductor muscles of the thigh; the *gluteal*, to the glutei and other external muscles of the pelvis; the *lateral sacral*, to the sacrum and its exterior muscles, and to the terminal portion of the spinal

chord; the *ischiatic*, principally to the muscular parts around the anus; and the *pudic*, which commonly affords branches to the uterus, the bladder, and the external parts of generation. The *external iliac* artery (142. A. *x. x.*), before escaping from the pelvis, through the crural arch, to become the *femoral*, gives off the *epigastric* which sends branches to the peritoneum, the scrotum, and adjacent parts, and establishes anastomoses with the *internal mammary* and the *inferior intercostals;* and the *circumflex ilii*, which supplies chiefly the anterior muscular parietes of the abdomen. The *femoral* artery, after furnishing several small branches chiefly to the muscles of the groin and lower part of the abdomen, gives off the large *profunda femoris*, which is extensively ramified on the powerful muscles of the thigh; and becoming *popliteal* behind the knee, the trunk divides, at a variable distance below that joint, into the great *anterior* and *posterior tibial* arteries, which descend, ramifying to the toes, like the radial and ulnar arteries of the arm.

The *femoral* artery divides higher in the ruminantia, and the two *tibials* anastomose behind the first phalanges of the foot. The branches which supply the legs of the ornithorhyncus, appear to be derived chiefly from the *internal iliacs*. The *femoral* artery in the plantigrade carnivora, divides into the two *tibials*, near the upper part of the thigh, and the *posterior tibial* forms the *internal* and *external plantar* arteries, below the middle of the tibia. In most of the lower nocturnal quadrumana, the *femoral* artery divides nearly as high as the crural arch, and its branches subdivide into anastomosing plexuses, as on the anterior extremities; and this subdivision into minute plexiform branches, takes place to a greater extent in the *femoral* arteries of the sloths and ant-eaters. The *external iliac*, in many orders of mammalia, gives origin to the *ilio-lumbar* artery, and the *profunda femoris* to the *epigastric*. The epigastric in the tiger arises from the internal iliac. In the large tailed quadrupeds, as the otter, the *external iliacs* are but moderate branches, from the great prolonged *aorta*, which, after giving off, as in most other mammalia, the *internal iliacs* separately, continues its course backwards under the bodies of the coccygeal vertebræ, sending off regular pairs of transverse branches at the vertebral articulations, like the *intercostal* and *lumbar* arteries of the thorax and abdomen.

The *internal iliacs* alone arise from the *aorta*, in the cetacea, there being no legs to necessitate *external iliacs*, and the *epigastrics* take their origin from the *internal iliacs*. The prolonged aorta, or *caudal artery*, of these animals, continues its trunk, rapidly diminishing, under the coccygeal vertebræ to beyond the first half of the tail, where it is at length entirely lost in the numerous plexiform branches, which it gives off in its whole course backwards from the abdomen. The trunk of the artery is thus far continued amidst its plexiform branches, as in the arms of the bradypus; but in the last portion of the tail, the artery is entirely reduced to plexiform branches, as in the extremities of the loris, the tarsius, and the myrmecophagæ. This plexiform condition is seen also in the *caudal artery* of the ant-eaters, and in the *internal iliac arteries* of the three-toed sloth. In the marsupial quadrupeds, the great development of the *external iliac* and the *caudal* arteries, and especially of the *epigastrics* which supply the mammæ and the pouch, and the small size of the *internal iliacs*, and their *uterine* branches, render these animals incapable of maturing a fœtus *in utero*, and necessitate an early abortion, as a normal character in that remarkable order of mammalia.

The capillaries into which the systemic arteries ultimately divide, after constituting plexiform ramifications in the tissue of every organ of the body, and transuding through their parietes the various materials of their nutriment, unite to form the branches of the returning *veins*. The *veins* convey the blood to the right side of the heart, from the anterior parts of the body, by one or two *superior venæ cavæ*; from the parts below the diaphragm, by one *inferior vena cava*; and from the heart itself, by one or more *coronary veins*. In the muscular and moving parts, as the extremities and the lungs, the return of the blood is aided by the development of numerous small semilunar *valves* in the interior of the veins, which are not required in those of the more tranquil internal viscera, as the brain and the liver. The venous blood collected from the brain and cranial cavity, is transmitted from the *sinuses* of the dura mater, through the posterior *foramen lacerum* on each side, into the two *internal jugular* veins, which, in descending along the sides of the neck, receive also the *lingual*, the *pharyngeal*, the *occipital*, the *facial*, and the *superior thyroid* veins, before they terminate in the great trunks of the *subclavian veins* (142. A. *a*. *b*.) The *external*

jugulars formed chiefly by the *temporal* and *internal maxillary* veins, and receiving the blood from the external and lower parts of the neck, enter likewise the *subclavian* veins, exterior to the former. In many of the inferior quadrupeds, especially in all the hybernating tribes, the venous blood is returned from the brain, not by the *internal jugulars*, but from the anterior ramus of the lateral sinuses, through the temporal canal on each side, into the *external jugular* veins, and also by the *vertebral veins* which here unite with the *external jugulars*.

From the anterior extremities, the blood is returned by the *cutaneous radial* and *ulnar*, or the *cephalic* and *basilic* veins, and by the deeper-seated anastomosing *brachial* veins which accompany the corresponding arteries throughout their ramifications, each artery being accompanied by two veins which freely anastomose with each other around that vessel. The union of these veins from the arm, forms the *axillary*, on each side, which, after becoming enlarged by the addition of numerous scapular and thoracic branches, is continued into the *subclavian*. The two *subclavian* veins, after receiving the *internal* and *external jugulars* and the two *vertebral veins* which follow the course of the vertebral arteries, become the *brachio-cephalic* trunks (142. A. B. *a*. *b*.), which form, by their union, in most mammalia, the *superior vena cava* (142. A. *c*.) In many of the inferior species of mammalia, however, as among the rodentia, monotrema, marsupialia, and in the elephant, the hedgehog, and some of the chiroptera, the *brachio-cephalic* veins continue separate to the right auricle, thus constituting two distinct *superior cavæ*, as found in birds and reptiles, and occasionally as an abnormal character in man. The *brachio-cephalics* receive also the *inferior thyroid*, and the *internal mammary* veins; and the *superior vena cava*, formed by their union, receives, in its course to the heart, some small *pericardial* and *mediastinal* branches, and the great *vena azygos*, which establishes important communications with several branches of the *inferior cava*. The *vena azygos*, in the ornithorhynchus, where the *superior cava* is double, opens into that of the left side. The blood conveyed by the coronary arteries to nourish the heart, is returned to the right auricle (142. A. *d*.), chiefly by one great *coronary vein*, which enters the back part of that cavity near the septum auricularum; where the

superior cava is double, the coronary vein enters the left superior cava, as in birds.

The *inferior vena cava* is single, receives the venous blood of the abdomen, pelvis, and posterior extremities, and conveys it to the right auricle (142. A. *d*.), to be sent with that from the *superior cava*, through the right ventricle and the pulmonary organs, for respiration. In the legs, as in the arms, the blood is returned by great subcutaneous veins, and by deep-seated *venæ comites* which follow, in anastomosing pairs, the course of the large arteries and their branches. The great *vena saphena interna* and the smaller *vena saphena externa*, like the cephalic and basilic veins of the arm, follow a superficial course on the leg; the former ascending along the inner part of the leg, after receiving the *superficial epigastric* and *pudic veins*, terminates in the trunk of the *femoral vein*, as high as the groin; the latter smaller branch, following an exterior and dorsal course, ends in the *popliteal vein*. The deep seated *anterior* and *posterior tibial* veins, and the *peroneal* branch of the latter, likewise unite to form the *popliteal vein*. Becoming *femoral* and *external iliac* (142. A. 1. 1.), the great vein of the leg, like the corresponding artery, receives the *internal iliac vein* (142. A. 2. 2.) to constitute, by their union, the trunk of the *common iliac* (142. A. 3. 3.)

The large branches of the *internal iliac* veins, derived from the viscera and parietes of the pelvis, anastomose freely with each other, and form numerous plexuses around these organs. The union of the *common iliac* veins (142. A. 3. 3.), forms the great trunk of the *vena cava inferior* (142. A. 4.), which in ascending along the right side of the aorta, to perforate the diaphragm, the pericardium, and the right auricle, receives the *middle sacral*, the *lumbar*, the *spermatic* (142. A. 5.), the *renal* (142. A. 7.), the *capsular*, and the *inferior diaphragmatic* veins, and the numerous trunks of the *venæ hepaticæ* (142. A. 8. 9.), which penetrate the *inferior cava* as it passes behind the liver. The veins from the chylopoictic viscera of the abdomen, form frequent anastomoses, and unite to constitute the two great trunks of the *splenic* (142. A. 10.), and *inferior mesenteric* (142. A. 11.) veins. The union of these venous trunks forms that of the *vena portæ* (142. A. 12.), which ramifies through the right (142. A. 14.), and left (142. A. 13.) lobes of the liver, accompanied by the ramifications of the *hepatic artery*. The united

capillaries of these venous and arterial ramifications, through the mass and around the *tubuli biliferi* of the liver, constitute the roots of the *hepatic veins* (142. A. 8. 9.), which enter the *inferior cava* before it perforates the diaphragm and pericardium to open into the lower part of the right auricle.

From the right ventricle, the entire venous blood of the system is sent through a single *pulmonary artery* (142. A. *l.*), provided with three semilunar valves with thickened margins, with corpuscula in their middle, and with fossæ behind them. The pulmonary artery divides into a right and left trunk (142. A. *n. m.*), each of which subdivides according to the divisions of the bronchi which they accompany, and to the number of the lobes of the lungs, around the cells of which they are distributed, as around the tubuli and cells of a gland—the lungs being merely a gland for secreting carbon, originating with a blastema and developing as other glands, and sending its secretion in a gaseous form through its duct, the trachea. The blood arterialized in the capillaries of the lungs, is returned to the left side of the heart, by a variable number of *pulmonary veins*, which open commonly by four or six or sometimes by two orifices unprovided with salves, or even by a single aperture, into the left auricle.

There is thus great unity of plan in the distribution of the arteries and veins throughout the vertebrated classes, and there is much analogy between the vessels of the anterior and the posterior portions of the trunk, and between those of the atlantal and sacral extremities. The *common iliac arteries* and *veins* are analogous to the arterial and venous *brachio-cephalics*, and their branches mutually resemble. The *superior vena cava* is single in the higher mammalia and in man, because their heart is placed farther backwards from the head, and the *brachio-cephalic veins* are thus enabled to unite before they arrive at that cavity. But in the inferior tribes, where the heart is situate more anteriorly in the trunk, the two *brachio-cephalics* enter that organ as separate superior *venæ cavæ*, before the extent of their course has allowed them to meet and unite. The *posterior vena cava* is longer than the *anterior*, throughout the vertebrata, as the abdominal or *posterior* portion of the *aorta* is longer than the *brachio-cephalic* or anterior trunks, because the heart, in this highest subkingdom of animals, constantly retreating from the head

as we ascend from fishes to man, has not yet reached the middle of the trunk of the body.

The various grades of development in the sanguiferous system, thus traced throughout the animal kingdom, are successively represented in the transient forms which this system assumes during its development in all the higher animals and man. The colourless blood of the *embryo* at first moves through the germinal membrane in two contiguous circles, like that of the lowest *annelides;* and when, at length, vessels are distinctly formed, the pale red blood continues to circulate in closed *arteries* and *veins*, without the aid of a heart, as in all the *radiated* and many higher tribes of animals. The pulsating, heart-forming centre of this system, becomes, as in worms and insects, a dilated dorsal vessel; and the *punctum saliens* forms a muscular *ventricle*, which developes an *auricle* behind it, and a *bulbus arteriosus* on its anterior part. Beyond this bulb, the *aorta* early divides into five successive pairs of deciduous *branchial arteries*, and the embryonic *branchial openings* on the sides of the neck have been retained to maturity, as an abnormal condition, in the human body. The cavities of the heart lose their primitive rectilineal position, which they retain in the *gasteropods*; the *auricle* gradually doubles up behind the base of the ventricle, and arrives at that dorsal position, with regard to it, which it retains in *fishes;* the two ends of the primitive, continuous, heart-forming, dorsal vessel, are now become *posterior vena cava* and *aorta*, where the blood still moves through the cavities of the heart, as in *insects*, from behind forwards.

The three anterior *branchial arteries*, forming simple *aortic arches* in man, as in mammalia, birds, and reptiles, are successively converted into the ascending trunks from the arch of the aorta. The fourth arch forms the descending aorta, and the posterior arch the pulmonary arteries, as during the metamorphosis of a frog. So that man's vascular system, arrived at the possession of a single muscular *ventricle*, represents that of the highest *crustacea;* with an *auricle* and *ventricle* placed in a line, it becomes that of a *gasteropod;* and with a developed *bulbus arteriosus*, an *auricle* advanced upon the *ventricle*, and the *aorta* divided into *branchial arches*, it is raised to that of *fishes* — the embryos of all

higher vertebrata. The development of a second *auricle* by a *septum* rising through the first, the partial division of the *ventricle* by a muscular *septum*, the imperfect separation of the venous from the arterialized blood, the entire metamorphosis of the *branchial arches*, and the development of the *pulmonary arteries*, change, at length, this system of the human embryo to that of an air-breathing *reptile*. The ascending *septum* of the yet single *ventricle*, draws up and cleaves the apex of the embryo's heart, and makes it double, like that preserved through life in the *lamantin* and the *dugong*; and this *septum*, on reaching to the origin of the still single *systemic artery*, divides it also to the extent of the *ductus arteriosus*, and entirely severs that portion, containing the pulmonary arteries, from the primitive *bulb* of the *aorta*. The septum of the *auricles* is developed in man, as in the reptile, before that of the *ventricles*; but the septum of his *ventricles* is necessarily completed, before the entire separation of the *auricles*, at birth, by the closing of the *foramen ovale*; and the reptile circulation of man in the amniotic fluid, must be continued for a time, by a different route from that followed in the air-breathing animal.

The *arterial* blood of the human fœtus (142. B. C.), as of other mammalia, aerated and replenished by traversing the *placenta*, is returned by the *umbilical vein* (B. 4.), to be sent, along with the visceral blood poured into it from the *vena portæ* (B. 1. 2. 3.), through every part of the *liver* (B. 5. 6). A small portion only of the placental fluid now follows its primitive course, from the *umbilical vein* (B. 4.) directly through the *ductus venosus* (B. 7.), into the inferior *vena cava* (B. 11.) The *portal* blood (B. 1. 2. 3.) entering the dilated *sinus* (B. 5.) of the *umbilical vein* (B. 4.), is distributed with that of the minute *hepatic artery*, chiefly through the *right* lobe (B. 6.) of the liver, which here is less than the *left*. The arterialized fluid received from the *hepatic veins*, (142. C. *c*.) and the *ductus venosus* (C. *b*.), is conveyed, along with the blood of the *abdominal cava* (C. *a*.), into the great *vena cava inferior* (C. *d*.) and the *right auricle* (C. *e*.) of the heart. By the aid of the *Eustachian valve*, it is directed from the *right auricle* (C. *e*.), through the *foramen ovale* (C. *p*.), into the *left auricle* (C. *f*.), where it mingles with the blood from the yet small *pulmonary veins* (C. *v*.) From the *left auricle* (C. *f*.), this aerated placental fluid is conveyed through the

left auriculo-ventricular orifice, into the *left ventricle* (C. *g.*) of the heart, by which it is propelled into the *aorta* (C. *h.*) and into all the branches (C. *i. k. l.*) ascending from its arch, to nourish and develope the brain, the organs of the senses, and all the important anterior parts of the body, so early and largely developed in the fœtus.

The blood thus rendered *venous* by affording nutriment to the larger anterior half of the body, is returned, in an impure state, by the *superior vena cava* (C. *n.*), to the *right auricle* (C. *e.*) By the right auriculo-ventricular orifice it passes directly into the *right ventricle* (C. *o.*), which propels it into the *pulmonary artery* (C. *r.*), the *ductus arteriosus* (C. *t.*), and the *descending aorta* (C. *m.*), to afford a scanty nutriment to the small posterior parts of the trunk and the limbs, and to proceed in mass through the large *umbilical arteries* (142. B. *u. v.*) for fresh oxygenation in the placenta. A small portion only of this blood is yet sent by the right (C. *s.* B. *h.*) and left (C. *u.* B. *i.*) branches of the *pulmonary artery* (C. *r.* B. *g.*), to the rudimentary and ineffective lungs; and the *external* and *internal iliacs* are yet but small branches of the great *umbilical arteries* which here form the bifurcation of the aortal trunk. Both ventricles thus combine, to propel the vital fluid through the system of the fœtus, and through the long and tortuous windings of the umbilical and placental vessels, and a mixed blood circulates through the arteries of the body, as through the body of a cold-blooded *reptile*. It is only by the subsequent closing of the *umbilical arteries* and *vein*, and the obliteration of the *ductus venosus*, the *foramen ovale*, and the *ductus arteriosus*, that man's circulating system is raised to the mammiferous type, after a proteus-like career through every inferior form presented by this system throughout the animal kingdom.

CHAPTER FOURTH.

ORGANS OF RESPIRATION.

FIRST SECTION.

General observations on the Respiratory Organs.

As the function of respiration is that by which the fluids of living bodies are oxygenated and decarbonized, and which renovates their vital properties, and prepares them for affording the materials of their various secretions, it is one of the most influential and most general in both kingdoms of organic nature. Every living plant has the power of decomposing the atmosphere, to effect its respiration, and every animal, from the monad to man, has the power of renewing the stratum of the surrounding element in contact with its exterior or its interior surface, to aerate the fluids of its body. The monad excites currents in the water around it, to aerate its surface, by the rapid vibration of its *cilia*, and man produces similar currents in the air, for the same purpose, by the alternate motions of his ribs and diaphragm, and by the myriads of vibratile *cilia* which line the mucous membrane of the passages and cells of his lungs. The absorption of oxygen from the atmosphere into the system, and the secretion of carbon from the living fluids, being always effected through delicate membranes constituting a respiratory surface, it is obvious that this chemical function may alike be performed by the general surface of the skin, or by the mucous lining of the alimentary canal, or by any external or internal organ especially appropriated to it. The lowest animals respire by their general cutaneous mucous surface, without a special organ for the convenient exposure of their fluids to atmospheric influence, and the external skin, or its internal mucous prolongation, is the origin of most forms of respiratory organs met with in higher tribes. The *gills* of aquatic animals, and the pulmonic cavities of the invertebrated tribes,

opening on the sides of their body, are but extensions of this general secreting integument. And the complicated *lungs* of the highest classes are but internal developments of its continuation, the alimentary canal, which, though they are adapted for an aërial product, present extensive secreting surfaces, with excretory ducts, and vesicular terminations of the tubuli, like other glands, to which they are allied in function, and in mode of development, as well as in general form and structure.

The respiratory apparatus of animals increases in extent with the general advancement of their organization, and the respiration is directly proportioned to their muscular force, to the temperature of their blood, and to the general energy of their functions. In the lowest animals, where the limited circulation and the limited sphere of activity, require no special respiratory organ, this function is effected by means of vibratile *cilia* disposed on their exterior, which are their common organs of locomotion, and which renew the stratum of the surrounding element in contact with their general surface; or it is effected by similar organs disposed on the mucous lining of their alimentary canal, which cause the external element to traverse and oxygenate that cavity. In most aquatic animals, however, with a distinct sanguiferous system, respiration is performed by more circumscribed *branchiæ*, developed from the exterior skin, like everted lungs, on which the blood is more or less extensively distributed, or by similar gills in the interior of the body, as in *echinoderma* and *rotifera*.

Air-breathing animals are furnished with pulmonary organs or *lungs*, closely allied to secreting glands, placed internally, lined with vibratile cilia, and opening either on the sides of the body, as in the invertebrata, or into the mouth, as in the vertebrated classes. The *lungs* present, as other glands, an extensive surface for the distribution of capillary blood vessels, and they are stimulated to activity by their own accumulated secretion. Their complicated function, embracing many mechanical and chemical changes, necessarily involves moto-sensitive, excito-motory, and sympathetic nerves, with voluntary and involuntary muscles, and the activity of this function in animals, is inversely proportioned to their tenacity of irritability and of life. The chemical changes effected by respiration are under the control of the minute grey filaments of the sympathetic

nerves with their microscopic ganglia, as all the other chemical functions of animal bodies. In the invertebrated classes, the heart is systemic, and rarely assists in transmitting the blood through the respiratory organs, but in all the vertebrated animals these organs receive the blood directly from a muscular ventricle, which thus contributes its force to augment the respiratory function. Respiration is the chief source of animal heat, it is a means of conveying odorous effluvia to the organs of smell in air-breathing animals, it is the principal stimulus to development in all classes, and its organs, by producing vocal sounds, give expression to the inward feelings, and afford a means of intellectual communication at a distance through the organs of hearing.

SECOND SECTION.

Respiratory Organs of the Cyclo-neurose or Radiated Classes.

As there is no distinct sanguiferous vascular system in *polygastric* animalcules, they appear to possess no special organ appropriated to the function of respiration, and the aeration of their fluids is effected through the thin pellicle which covers their exterior, or through the mucous lining of their alimentary cavities. The respiratory currents are produced by minute vibratile *cilia*, variously disposed over the surface of the body, or around the buccal orifice; and probably lining the alimentary canal, and the peritoneal cavity where a cyclosis of particles is observed. These vibratile filaments, thus early connected with the function of respiration, and here serving also as organs of locomotion and even of prehension, appear to form a part of the respiratory apparatus of all the higher aquatic invertebrata, and line the pulmonary organs throughout the vertebrated classes. Those *polygastrica* which are covered externally with a horny sheath, or with articulated laminæ of silica, appear to respire by internal currents through the buccal orifice, as in vaginiform zoophytes. The internal cyclosis of the larger forms, as paramæcium, and the reticulate cutaneous connecting vessels of the compound forms, as volvox, may also aid in this function.

The entire gelatinous substance of *poriphera* is respiratory, and the incessant currents of water through the pores, canals,

and vents oxygenate every part of the exterior and interior of their body. Vibratile cilia are also the agents of the respiratory currents in the adult and the embryo-state of *polypipherous animals*, where these minute organs are disposed along the sides or around the external periphery of the tentacula, or line their interior; and they line the buccal and gastric cavities of the polypi, and their prolonged canals which circulate nutriment through the body. In *hydra* and *actinia*, the respiratory currents of water enter the stomach by the mouth, and are seen passing to and fro within the ciliated cavities of their tubular tentacula; and indeed nearly the whole exterior surface of the body and every internal organ, in the latter genus, are closely covered with very minute vibratile cilia, and are bathed by the aqueous currents of respiration.

Although almost every kind of zoophyte is cilio-brachiate, like actinia, and is amply provided with these minute organs on the interior mucous lining of its alimentary apparatus, the larger forms of symmetrically disposed brachial cilia are generally confined to the lateral margins of the tentacula, along which they move in very regular waves, following always the same apparent direction, from the mouth of the polypus on one side of the tentaculum, and towards the mouth on the other; but the direction in which these cilia actually move is nearly vertical to the apparent plain of the entire waves. The vibratile cilia are thus disposed on the sides of the arms in most of the lower zoophytes, as *alcyonium, flustra, cellaria, serialaria, plumularia* and *sertularia*, which extend their elastic tentacula in a regular campanulate form, while the ciliary currents flow towards the polypi, acrating their surface and bringing food to their mouths from a distance. These tentacula when severed from the body of the polypi, continue to vibrate their cilia, and swim by their action like worms through the water: thus showing, as in the vibratile cilia of the mucous and serous membranes detached from the body in all higher animals, the independence of their movements on consciousness or volition, and their similitude, in this isolated condition, to reflex or sympathetic phenomena.

The number of tentacula, like the number and size of the cilia, varies much in different zoophytes, there being but six tentacula in some *hydræ*, eight in *plumularia falcata, serialaria lendigera*, and many of the higher genera as, *lobularia, pennatula, virgularia, isis, corallium*, and *gor-*

gonia, ten in *alcyonium gelatinosum*, fourteen in *cellaria avicularia*, twenty-two in *flustra carbesia*, and higher numbers in *alcyonella, tubularia, caryophyllia, actinia,* where they form two or more series around the mouth. In some polypiphera, as *lobularia, pennatula, gorgonia,* where the large tentacular cilia are not vibratile organs, the respiratory currents and food are directed to the mouths of the polypi, by the minute vibratile cilia which line the buccal and gastric cavities. So that the whole interior of the polypi, and their prolonged tubular canals, are aerated by the ciliary currents of the surrounding element, in the minutest compound zoophytes, as in the larger isolated forms of actiniæ.

The large fin-like vibratile cilia of *beroë* and other *ciliograde acalepha,* disposed in symmetrical longitudinal columns, and serving as organs of locomotion, like those of polygastrica, must also contribute to the respiratory function, by constantly renewing the stratum of water in contact with the thin pellicle covering the exterior of their soft body. These organs, however, are not branchial lamellæ, destined to support the ramifications of blood vessels, as in crustacea and fishes. In the empty state of the alimentary canal, the currents of water directed over its ciliated surface, passing straight through the axis of the body, will likewise aërate the mucous lining of that passage, as in polypi, and even in fishes. In the gaseous swimming vesicles of the *physograde* species, as the *physalia,* we already observe the analogue of the air-sac of fishes, and the first rudiment of the lungs of higher vertebrata, although they are not yet subservient to aërial respiration. In many of the *palliograde* species, as *aurelia,* the four ovarial sacs opening around the stomach, below the mantle, and separated from the gastric cavity by thin septa, appear to extend the respiratory surface; but the greatest respiration of these animals is probably effected by the vascular and active peripheral margin of the mantle, and by passing currents of the surrounding element through the whole ciliated interior of their body, as seen when they are placed alive in sea water artificially coloured.

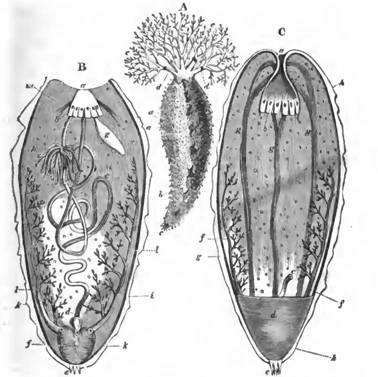
More distinct and more complex organs are appropriated to the function of respiration in the *echinoderma* than in any other radiata, which accords with the higher development of all their other organs. In the *asterias,* the upper surface of the

body is covered with innumerable minute transparent colourless fleshy tubes, which, in the living state, are seen to rise and sink incessantly through openings of the skin, conveying water by their ciliated parietes, for respiration, into the interior cavity of the body. Though very minute, these respiratory tubes resemble in form, the large inferior prehensile feet extended through the ambulacral apertures, being, like them, nearly cylindrical and provided with terminal openings. The whole exterior and interior surfaces of the body, and of its internal organs, and of the long ambulacral feet, are likewise provided with vibratile organs and aërated by ciliary currents, like the mucous and serous surfaces of other radiata, and of most aquatic invertebrata. They cover the exterior of the prehensile tubular feet of echinoderma, and even the investing cutaneous membrane of the spines on the exterior of *echini*. The prehensile ambulacral feet are extended by having fluid injected into them from vesicles at their base, and these communicate by membranous canals with a vascular apparatus disposed around the mouth. The surrounding element enters the peritoneal cavity by numerous small membranous tubes, disposed around the lower aperture, and bathes the abdominal viscera, in the echinida, as in the asterida, and the vibratile cilia covering all the internal and external parts of the body, incessantly renew the stratum of water in contact with their surface, so as to aërate every part of the vascular system and the various tissues of the body.

The whole irritable exterior surface of *holothuria* is respiratory, and the ciliated tubular feet which extend in longitudinal rows from its surface, and the ramified, ciliated sheathed tentacula which surround the mouth, as the external parts of other echinoderma and most radiata, as seen in the annexed figure of *holothuria spinosa* (Fig. 143. A. B. C.) from Port Jackson, of a red colour, and covered with calcareous spines, like an asterias; but the internal apparatus appropriated to this function, and their communication with the surrounding element, are more circumscribed, and they approach nearer to the type of these organs in higher animals. Instead of entering the general cavity of the peritoneum by numerous minute orifices, as in asterida and echinida, the water is inspired by *holothuria* solely through the cloacal aperture (143. B. C. *e. e.*),

and is confined to the interior of one or two hollow ramified tubular branchiæ (143. B. *l. l.* C. *f. f.*) attached by a fold of peritoneum to the sides of the abdomen, and which communicate externally only by one or two orifices leading into the cloaca (143. B. *f.*) The parietes of these internal branchiæ, which ramify throughout the whole interior cavity of the body, like the tracheæ of insects, have distinct

Fig. 143.



transverse and longitudinal muscular fibres, and support the ramifications of the sanguiferous vessels containing the venous blood of the system, like the internal pulmonary organs of air-breathing animals, which they also resemble in their rythmic movements of dilatation and contraction; and many larvæ of aquatic insects inspire, like *holothuria*, through the anus and the cloaca.

THIRD SECTION.

Respiratory Organs of the Diploneurose or Articulated Classes.

In the sluggish *helminthoid* classes of articulata the respiration is nearly always aquatic, but in the active *entomoid* classes it is most generally aerial; and in the simpler forms of *worms*, as in the lower *radiata*, no special organ appears to be appropriated to this function. From the internal habitation of the *entozoa*, and the general softness and vascularity of their exterior covering and their component tissues, they appear to be oxygenated directly by the contact of the fluids of the animal in which they are parasites, like a fœtus in utero, an ovum, a gemmule, or a portion of the body itself; the possession of special pulmonary or branchial apparatus, would be unavailing in animals permanently buried in the substance of the brain, the liver, or similar internal organs, and with so limited a circulation of the blood, and where their temperature is not dependent on their own vital functions.

The subcutaneous situation of the transverse abdominal blood vessels of the *rotiferous animalcules*, and of their vascular plexus around the neck, their thin soft and generally naked skin, and the ciliary currents almost constantly flowing over its surface, together with the ciliary movements produced in their wide buccal and gastric cavities and even in their general peritoneal abdominal cavity, contribute to the extensive aeration of their ever-active body, independently of the distinct branchial organs which have been detected in several species. The branchiæ are here placed in the interior of the abdominal cavity, as in holothuria; they are furnished with large vibratile valvular cilia, like many crustacea; they communicate with the exterior medium by a single median dorsal aperture near the neck, and they are symmetrically disposed on the two sides of the abdominal cavity. Eight of these branchial organs, placed apart from each other, and attached to internal lateral tubes, apparently the testes, are seen in the transparent abdomen of the *hydatina senta*, with their vibratile laminæ in constant action.

The branchiæ of the *cirrhopods* are short laminated

pyramidal organs, varying in number, size, and form, in different species, attached to the sides of the trunk, or to the bases of the proximal pairs of articulated feet, like those attached to the haunches of the legs in the higher forms of crustacea; and they aerate the blood spread upon their numerous component laminæ, before it is transmitted to the pulsating dorsal vessel for distribution through the system.

The *red-blooded worms* have the greatest activity, and the most extensive sanguiferous system of all the helminthoid classes, and they present a corresponding development of the respiratory organs, which are most generally branchial, sometimes external, sometimes internal; some respire by the naked ciliated surface of their body, and a few possess internal pulmonary sacs for an aërial respiration. The vascularity of the skin, and the incessant currents of water over its exterior, produced by minute vibratile cilia which cover its naked surface, appear sufficient to oxygenate the fluids in some of the lower annelides, as the *planariæ*, which present no special organ appropriated to respiration. No distinct branchiæ have been seen in the *nais*, the *gordius*, and some other genera of the *abranchia* of Cuvier; but the tubicolons annelides, whether secreting calcareous shells, or constructing adventitious tubes of sand or mud, are generally distinctly *cephalo-branchiate*, having regular ramified tufts, or elegant plumose expanded branchiæ, covered with vibratile cilia, and symmetrically disposed on the head or anterior part of the body, as in *sabella*, *serpula*, *terebella*, *amphitrite*, and *pectinaria*. These organs, in the living animals, are commonly a little extended from the orifice of the tubes, and expanded to receive the full influence of the ciliary currents, on the red blood distributed through their minutest ramifications. Most of the naked and burrowing aquatic annelides are *dorsibranchiate*, having the branchiæ in elegant arborescent tufts, symmetrically arranged along the exterior and dorsal aspect of the segments, or in form of more simple branchial sacs confined to their interior. In *amphinome*, *hipponoe*, *pleione*, and *nereis*, these ramose branchial tufts accompany the upper pairs of lateral feet nearly along the whole extent of the trunk. They are more concentrated in their distribution in *arenicola*, where they are confined to a limited number of the segments in the middle portion of the

trunk, but they are individually more ramified and lengthened, and they exhibit most regular movements of expansion and contraction as they receive or expel the red blood transmitted by the branchial vessels. In the common *arenicola piscatorum*, there are thirteen pairs of these branched organs along the dorsal part of the body, and three or four segments of the trunk intervene between each pair of branchiæ. In *polynoe*, the branchiæ are in form of thin dilatable membranous sacs disposed externally along the whole extent of the sides of the trunk. The branchiæ are also in form of membranous sacs placed along the dorsal part of the body in aphrodita (*halithea*, Lam.) where they are sometimes concealed by an external fibrous reticulate covering, as in *halithea aculeata*, or exposed on the exterior of the back, as in *halithea squamata*. There are thirty compressed dorsal respiratory sacs in the *halithea aculeata*, disposed in fifteen symmetrical pairs, along the whole extent of the body, with fourteen pairs of much smaller crested or serrated sacs interposed between the larger. They all communicate, at their inferior margin, with a distinct closed dorsal respiratory cavity, extending along the whole body, and separated by its thin parietes from the abdominal cavity, and from the reticulate texture covering the back. The sacs open also externally by minute compressed lateral stigmata concealed in deep depressions between each pair of feet, and there are two large openings into the general respiratory cavity, placed at the sides of the buccal orifice.

There are nearly twenty pairs of isolated internal, highly vascular, respiratory sacs, disposed along the whole abdominal cavity of the leech, *hirudo*, lined each with a soft secreting mucous membrane, covered with a peritoneal coat, supplied with vessels from the great lateral trunks, opening by small round stigmata on the ventral surface of the body, and the pairs separated from each other by about five segments of the trunk. Similar minute, isolated, internal, lateral, respiratory sacs are disposed in regular pairs along the whole extent of the abdominal cavity in the earth-worm, *lumbricus*, which, like those of *halithea*, and *hirudo*, are largest in the middle portion of the trunk; they become almost imperceptible towards the ends; they generally contain a white mucous fluid, and they open separately by

small round stigmata on the sides of the segments. These simple internal sacs of the *earth-worm* and the *leech*, opening by minute stigmata on the surface of the skin, and receiving a large portion of the venous blood of the system on their highly vascular mucous lining, may be adapted both for an aërial and aquatic mode of respiration, or they may receive air from the water itself: and there is thus a gradual transition from the external and internal branchial sacs of *polynoe* and *halithea*, to these internal rudimentary lungs of the highest pulmonated annelides, where we already observe the commencement of the spiracula, and even of the tracheæ of the entomoid classes.

In the entomoid classes, the respiration is generally aërial and extensive, which accords with their increased muscular energy, and with the high temperature they often exhibit in their living and active state. In the *myriapods*, the most vermiform of all the entomoida, the respiratory organs are adapted solely for atmospheric air, and consist of ramified tracheæ, which commence by stigmata opening on the sides of the segments, or sometimes, as in *scutigera*, on the middle of the back, where they lead to small air-vesicles. These air-tubes in the *scolopendra*, open on each side of the alternate segments along the whole extent of the body, and they divide immediately at their origins in the stigmata, into numerous large branches, which form partial anastomoses with those of the adjoining segments, without constituting, as supposed by Meckel, the large continuous lateral trunks seen in the tracheæ of insects.

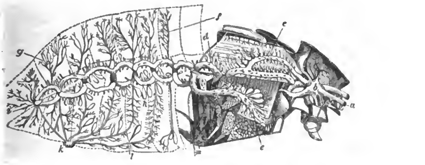
Insects are generally provided, in the larva as well as in the adult state, with nine or ten pairs of valvular spiracula, defended externally by firm margins, sphincter apparatus, and surrounding converging hairs, disposed on the sides of most of the abdominal and thoracic segments, and leading to tracheæ which ramify through every point of the system. They exhibit rithmic contractions and expansions of the abdominal cavity during respiration, as in pulmonated vertebrata; and many, especially of the neuropterous larvæ, possess also branchiæ for aquatic respiration, which are sometimes deciduous and sometimes permanent, as in the caducibranchiate and perennibranchiate *amphibia*. The branchiæ appear to separate air from the water and convey

it to the internal tracheæ, and some coleopterous insects and dipterous larvæ inhabiting the water, come, like cetacea, to the surface to inhale atmospheric air. The branchiæ, indeed, are mere external prolongations of the commencements of the internal air-tubes, and assume the form of capillary filaments, or ramose tufts, or lamellæ, through which the tracheæ pass; at their metamorphosis, they often lose these branchial terminations of the tracheæ, and acquire spiracula for aërial respiration. The aquatic larvæ of the common gnat, and of the hydrophilus, chironomus, and dytiscus, inhale air by stigmata near the anus, and the last segment of the trunk is prolonged into an air-tube in the stratiomys and in the larvæ of eristalis, which they extend to the surface of the water. The deciduous external branchiæ prolonged from the internal tracheæ of the larvæ of many insects, thus resemble the external deciduous branchiæ prolonged in filiform tufts from the permanent organs in many of the higher fishes.

The tracheal openings of perfect insects are provided with muscles to open and close them, as shown by Lyonet; they are often extremely minute or entirely wanting on the posterior segments of the abdomen and of the thorax, and they are generally largest on the anterior rings of these two divisions of the trunk, even where the posterior have been largest in the larva. The tracheæ are lined internally with a soft, white, mucous tunic; externally they are covered with a more dense, shining, serous coat, and between these is an elastic fibrous tunic, composed of continuous spiral filaments, twisted closely, like those of a plant, around all the ramification of the tracheæ, from the spiracula to their minutest divisions, thus giving the necessary elasticity for the free passage of air through all parts, as the cartilaginous rings of the trachea and bronchi of vertebrata. These air-tubes ramify, like blood-vessels, through all parts of the head, the antennæ, the palpi, the legs, the tarsi, the wings, the muscular system of the trunk, the interior of the blood-canals of the wings, the surface of the alimentary canal, the ovary, and on almost all the internal organs, as seen in the annexed figure (Fig. 144,) of the tracheæ of *melolontha vulgaris*. From the stigmatic origin of each tracheæ, there generally extend forwards and backwards several large longitudinal trunks (144. *b. c.*)

which, by anastomosis, establish a free communication with the adjoining stigmata of the same side; there are also several transverse anastomosing branches, (144. *h. l.*) which unite below (144. *k.*) with those of the opposite side, to form a free communication between the two sides of the body; and there are numerous other branches (144. *f.g.*) from the same tracheal

Fig. 144.



origins, which ramify directly on the various organs of the body.

Sometimes, as in *blatta* and *locusta*, the longitudinal branches form but one dorsal and one ventral median trunk, from which branches are distributed to the organs, and between which a free communication is established by regular transverse anastomosing branches. The longitudinal lateral trunks are often much dilated in aquatic insects, to render them buoyant, and to provide for their interrupted respiration; and the aquatic larvæ of several insects, as of *libellulæ*, inspire air solely from water regularly introduced and expelled through the anus, as *holothuriæ* inspire water for respiration by the same orifice. In the rectum or cloaca of these larvæ, indeed, there are several compact rows of triangular branchial lamellæ, which line its whole parietes, and which support the capillary extremities of the abdominal tracheæ; some have as many as eighty of these plates, disposed symmetrically in rows of pairs within the rectum. Besides the minute cells, (144. *d. e. f. g.*) in which, as in the lungs of vertebrata, the tracheal ramifications of the higher insects frequently terminate, there are often more considerable vesicular dilatations on the great lateral longitudinal

trunks, and other large tracheæ, as in many adult dipterous and hymenopterous species and aquatic coleoptera; such vesicular enlargements of the tracheal trunks of insects are seen in the head, the thorax, (144. *b*.), and especially the anterior part of the abdomen; they lighten the body in flying forms; they are covered with minute transparent spots like perforations; they are not developed in larvæ; and they often give origin to the visceral branches. The common entomoid form of the respiratory organs is seen even in the apterous species, as the louse, *pediculus*, where there are seven pairs of lateral stigmata, opening into two longitudinal tracheæ, which extend, without dilatations, along the whole body, and communicate with each other by numerous anastomosing branches. And thus the limited circulation of the blood in insects is compensated for by the extensive ramification and distribution of the respiratory organs through every texture of their body, and the necessary lightness, elasticity, and muscular energy are imparted to these invertebrated winged inhabitants of the air, and hence the high temperature which their body, as has been long known, often acquires.

In the *arachnida*, the more extensive circulation of the blood through the body is accompanied, as in annelides, myriapods, and crustacea, with a more concentrated form of the respiratory organs than occurs in most insects; and, as in insects, they are always adapted for aërial respiration, whether they belong to aquatic or terrestrial species. Some aquatic forms of arachnida, as some aquatic insects, appear to respire under water by means of the globules of atmospheric air which they carry with them into that element, entangled among the hairs of their surface. In the phalangium, and other tracheated species, the air-tubes divide into branches from their commencement in the lateral stigmata, as in myriapods, and these branches communicate freely with each other by transverse and longitudinal anastomoses. The stigmata have generally a more ventral aspect in the arachnida, especially in the higher pulmonated forms, as the scorpions and spiders, where no tracheæ extend through the body. Some arachnida, as the *dysdera* and *segestria*, have been shown by Dugès to be at the same time possessed both of ramified tracheæ and pulmonary sacs, the two posterior of their four stigmata opening into branching air-

tubes, and the two anterior into circumscribed pulmonary cells.

Of the pulmonated forms, some, as the scorpion, have eight distinct internal respiratory sacs, opening by separate stigmata; others, as mygale, have four sacs, and the most concentrated form of these organs is that of the spiders, which have only two symmetrical pulmonary cells. On the ventral surface of the abdominal segments of the scorpion, four pairs of elongated oblique stigmata open into eight broad short quadrangular sacs, each of which is divided into nearly twenty small flat cells, by internal parallel septa, giving a pectinated appearance externally to the shut margin of the sac, which may be compared to the incipient development of peripheral cells in the lungs of reptiles. Four similar sacs, also with soft white vascular parietes, open, by four stigmata, on the ventral surface of the abdomen in the mygale, and one similarly divided pulmonary sac opens, in spiders, by a transversely elongated stigma on the anterior part of the ventral surface of the abdomen. There is thus, in passing through the tracheated, the pneumo-tracheated, and the pulmonated forms of arachnida, a gradual transition from the highly ramified and extended condition of the respiratory organs of insects, to the more concentrated and laminated structure presented by the branchiæ of crustacea.

As the blood is most extensively circulated through the body in *crustaceous animals*, and their respiration is only aquatic, their branchiæ present an extensive surface, and consequently a laminated structure, to receive a larger portion of venous blood in capillary vessels, for aeration. The gills are here generally attached to the bases of the articulated feet, whether these lateral appendices of the segments be masticatory, ambulatory, natatory, ovigerous, or simply respiratory; and they receive the venous blood of the system before returning to the heart, for distribution through the body. In the lower orders of crustacea, the branchiæ are commonly confined to the appendices of the segments near the caudal end of the trunk, where they hang free in the surrounding element, and are rapidly moved to and fro by the organs which support them, as by vibratile cilia. But in the higher species, they are attached to the ambulatory and masticatory appendices near the cephalic extremity of the body,

where they are concealed beneath the sides of the dorsal carapace, in a thoracic cavity separated by a tendinous diaphragm from the abdomen.

In many of the lower suctorial parasitic crustacea, as the *caligus*, no special organs for respiration have been detected, and they may be aerated through the soft naked surface of their body. The branchiæ have the simple form of flat vascular membranous folds, or vesicular lamellæ, attached to the thoracic feet in most of the branchiopodous species. They are also, in the amphipoda, in form of membranous foliated expansions, highly vascular, attached naked to the thoracic feet, and rapidly moved to and fro by them, for the aeration of the venous blood extensively spread on their surface; they form small membranous sacs attached to the thoracic appendices in the læmodipoda. They are exposed membranous, sometimes ramified laminæ, attached to the abdominal feet, in the isopods; and, with the same position, in most of the stomapods, as in the squillæ, they constitute flabelliform series of small pectinated tubes, while in others of the same order, as the cynthiæ, they form a small pedunculated membranous cylinder. The five pairs of broad natatory abdominal feet of the *limulus* support, on their posterior surface, innumerable delicate exposed branchial filaments, composing the respiratory organ; and the anterior five pairs of abdominal feet, in the *squilla*, support as many pairs of peniform ramified tubular branchiæ.

The branchiæ, or the elementary pieces of the feet subservient to respiration, are, in the decapods, more developed and more complex, though not more numerous, than in most of the inferior crustacea; and they are disposed in two lateral longitudinal rows of vertical laminated pyramids, attached to the bases of the five pairs of ambulatory, and the three outer pairs of masticatory, appendices. They are concealed in a respiratory cavity, formed by the lateral overhanging folds of the carapace, which gradually extends downwards, to cover them during their earlier development; and in this cavity they are fixed below by the bases of the several branchial foliated pyramids, and their free apices converge above. In the brachyourous decapods, the branchial laminæ composing the ten or eleven vertical pyramids on each side, are more simple, and present a smaller extent of surface for the distri-

bution of blood-vessels, than in the macrourous species, where there are about twenty-two pyramids on each side, and their component laminæ are subdivided into innumerable small filaments, so as to present a more extended respiratory surface. The laminæ of each pyramid are disposed in two vertical rows, with their flat surfaces superimposed; there are sometimes two hundred laminæ in a single row; and between the branchial pyramids of each pair of feet, a long horny lamina is extended upwards, by the constant action of which the currents of water are directed forwards over the branchiæ. In many of the brachyourous decapods, where the branchial cavity and its openings are more circumscribed, the currents are generally directed inwards through an inferior orifice on each side, by the movements of a small horny valvular lamina attached to the base of a maxilla, and the water passes out by a superior vent, on each side of the mouth, after bathing the surface of the gills. During the development of the complex branchial apparatus in the decapods, the highest order of crustacea, they are observed to pass through successive conditions of structure, much resembling the various permanent forms presented by these organs in the lower orders of this class. For a time, they are not developed from the feet of the embryo; next, they are observed as simple rudimentary processes, of indeterminate function; later, they become distinct, vascular, naked, respiratory laminæ; and lastly, they fold up under the projecting carapace, and become concealed under its margins.

FOURTH SECTION.

Respiratory Organs of the Cyclo-Gangliated or Molluscous Classes.

All molluscous animals, excepting a few pulmonated gasteropods, are aquatic, and breathe by means of branchiæ, which present no less striking diversities of form and structure than are seen in most other organs of the body in this most diversified subkingdom. From their aquatic and limited respiration, their muscular energy is more feeble, their movements are more slow, their whole functions more languid,

and their temperature lower than in most of the active, air-breathing articulated tribes. As the development of vibratile cilia, on the respiratory apparatus of animals, is generally inversely proportioned to the other means of activity possessed by these aërating organs, they are most developed, most numerous and constant, and most extensively distributed on the branchial apparatus of the languid and inert molluscous classes, where they were already observed and described on the branchiæ of conchifera, before the time of Leuwenhoek. These minute vibratory organs not only cover the filaments of the branchiæ, and line the whole respiratory cavities, but are seen also on most of the naked parts of the exterior, and even in the alimentary canal, as in many lower invertebrata; and the involuntary character of their movements was known to Leuwenhoek, who saw them moving on pieces of the branchiæ of the common muscle, *mytilus edulis*, detached from the body. The respiratory currents of *tunicata*, when their body is perfectly motionless, were known to Cavolini, who justly compared those of *ascidia* to the currents which bring food to the polypi of zoophytes; and Basterus referred to the ciliary movements of the branchiæ extending a little beyond the edge of the shells, the spontaneous motions which he often observed in newly hatched embryos of the oyster.

The *tunicata* breathe by reticulate branchiæ, occupying the interior of a large thoracic cavity, which receives the ciliary currents by the large respiratory orifice, and expels the water by the common vent of the branchial, the alimentary, and the generative organs. In the long narrow cavity of the *salpa*, they are disposed transversely in rings or spiral turns, giving an annulated appearance to that cavity, compared to a trachea by Chamisso, as seen through the transparent parietes of the body. In the higher forms of this class, the branchiæ generally constitute a more continuous lining of the respiratory sac; and the inhaled currents pass through their elongated oval or quadrangular meshes, to arrive at the efferent canal and exterior vent. Although the elasticity of the exterior tunic of these animals is capable of assisting in inspiration, and the contraction of the muscular tunic or mantle, everywhere attached to its interior, contributes occasionally to rapid and powerful expiration, yet the

orifices are most open, and the respiratory currents are most active, when all these parts are entirely quiescent. The same currents which aerate the branchiæ by passing through their innumerable meshes, bring also floating particles of food to the mouth, placed in a recess at the bottom of the respiratory cavity.

The vibratile cilia, which alone produce these equable and constant currents, I have found of minute size, compactly disposed over the entire breadth of the reticulate filaments of the gills, lining the smooth parts of the branchial sac, covering even the tentacular filaments at the orifices, and moving in most regular waves around all the meshes of the branchiæ, as around the arms of a polypus. On being irritated, the ascidiæ contract the mantle forcibly, and throw the contained water to a distance from both orifices, the direction of the respiratory currents being determined not so much by valvular structure, as by the impulse of the waves of minute vibratile cilia, which here, as in all other cases, continue to vibrate on small pieces detached from the gills. The vibratile cilia, in these inert and often fixed animals, thus serve to aerate the venous blood of the system, before being transmitted to the heart, and they bring food to the mouth with the respiratory currents; in the swimming species, they are also, as in the ciliograde acalepha, the means of locomotion; in the luminous tunicata, as pyrosoma, they appear to be connected with that remarkable property of emitting light, as I have found them to be on the surface of *beroe*, and in the ciliated intestine of some luminous annelides; and they assist in removing all excretions and foreign particles from the interior of their body.

In the respiratory organs of the *conchifera*, as in most other organs of their body, the general plan of structure is nearly the same as in tunicata, and they are very uniform throughout the class. Here, as in tunicata, the mantle presents two apertures, a respiratory orifice and a vent, communicating with the branchial cavity, for the reception and exit of the ciliary currents, and the buccal orifice of the alimentary canal is situate at the bottom of this cavity. The vibratile cilia, often of great size and bent, as in *mytilus*, cover closely the whole surface of the branchial meshes, line all parts of the respiratory cavity, extend over the mucous covering of

the viscera, the labial appendices, the mantle, and its fimbriated tentacular prolongations, and even line the interior of the alimentary canal. A pair of double pectinated branchial folds, on each side of the foot, within the mantle, are suspended in the branchial cavity, fixed by their two contiguous upper margins, free below, and at their two upper remote margins, each fold forming a loose, compressed, reticulate sac, and supporting on its innumerable minute elongated meshes the capillaries of the branchial blood vessels. In the conchifera, which burrow in rocks, timber, mud, sand, or other materials, the mantle and the respiratory cavity are necessarily prolonged, to bring the two orifices of the palleal cavity within reach of the surrounding element, and the branchiæ are greatly elongated.

Each pendent gill is composed of two nearly contiguous pectinated laminæ, united to each other below, enclosing between them a narrow space, widening above, and allowing the transmitted aqueous currents to pass over one free upper margin, into the canal of the expiratory vent. As the contiguous sides of each lateral pair of gills are continuous at their upper margin, where they are fixed, and at their free margins below, the entire pair of one side in the conchifera may be considered as only a puckered or folded condition of the simple expanded reticulate membrane lining either of the two sides of the respiratory cavity of a cynthia or other tunicated animal. The compressed filaments which compose the branchial laminæ are slightly connected together by regularly disposed tubercles, whose contiguous surfaces appear to be also provided with minute slow moving cilia; these component fibres of the branchiæ are nearly free in *pecten*, *arca*, and *spondylus*, and are united only at their distal ends in the *malleus*. The branchial laminæ are sometimes unequal in size, as in *cardium*, where the exterior are not half so large as the interior laminæ. The branchial currents of conchifera bring food to the mouth placed at the bottom of the respiratory sac, they assist in removing the excretions and the ova or embryos from the cavity of the mantle, and they may aid in clearing or enlarging the perforations made by burrowing species. Small portions of the branchial laminæ, detached from the body, continue long their ciliary movements, and present the most favourable

means of examining this unexplained phenomenon. In marine species, their movements are quickly arrested by immersion in fresh water, and by sea water in the palustrine forms.

Nearly all the *gasteropods* breathe, like the other molluscous classes, by means of branchiæ, which are disposed externally in the naked species, and are generally concealed under the mantle in the testaceous forms; a few species only breathe air by a pulmonic cavity opening on one side, some of which are aquatic in their habits, others terrestrial. The naked gasteropods, like the naked annelides, have greater latitude of surface than the testaceous forms, for the distribution of their external ciliated branchiæ, and of their general ciliary currents; and, indeed, their whole surface is often ciliated and respiratory. The branchiæ in these species are generally disposed, as in the dorsibranchiate annelides, in ramose tufts, symmetrically arranged over a greater or less extent of the dorsal or lateral parts of the body; but the modifications of form and structure which they present are too numerous and diversified to afford satisfactory means for the zoological subdivision of this class. In *scyllæa,* they are disposed in isolated, ramified, small tufts on the outer surface of the extended dorsal folds of the mantle, and on the surface of the back; in *tritonia,* as in arenicola among the annelides, they rise more directly in elegant ramifications, along each side of the back; in *eolidia* and *cavolina,* they form numerous rows of small simple clavate projections, similarly disposed along the back; and in *tergipes,* a single row on each side; in *tethys,* the two dorsal rows are composed of alternately disposed tufted and crested branchiæ; and in *glaucus,* they form long filiform extensions from the ends of the lateral palleal appendices. In the *tritonia* and similar forms, the number of branchial pairs varies with the degree of development of the body, and they are developed successively from the front pair backwards.

In the *doris,* the branchiæ form elegant plumose or ramose tufts around the anal opening on the posterior part of the back; they constitute a single penniform organ, under the margin of the mantle, on the right side, in *pleurobranchus* and *pleurobranchæa;* they are protected by a thin pellucid shell, on the right side of the body in *aplysia,* and on the middle

of the back in *carinaria*. In *patella* and *chiton*, they form a circular range of branchial laminæ around the body, between the margins of the mantle and foot; but in *pleurophyllidia*, they are confined to the two sides of the body, the circle being interrupted before and behind. In the *haloitis*, they constitute two unequal penniform organs, placed under an extended fold of the mantle, on the left side of the body; and the same character is found in the pectinibranchiate gasteropods, inhabiting nearly all univalve, unilocular, turbinated shells, and forming the largest order of this class. The branchiæ when confined to the right side in gasteropods, are commonly single, and when confined to the left side, they are thus generally double penniform organs. The two penniform pectinated gills of the pectinibranchiate species, are placed in a recess on the left side of the back, under the open parieties of the mantle, and, as usual, near to the auricle and ventricle of the heart, which receive the aerated blood.

The muscular and ciliated syphon, prolonged from the left side of the mantle, and extended through the canal or groove of the shell, directs the respiratory currents inwards over their surface; and the water, interrupted by the closed cavity of the mantle behind, after bathing the entire ciliated branchial laminæ, and the ciliated respiratory cavity in which they are lodged, passes outwards over the right side of the palleal cavity, and over the muciparous follicles and the excretory orifices there placed. The development of the vibratile cilia over all parts of the branchial apparatus and external soft parts of gasteropods accords, as usual, with the limited means otherwise provided for renewing the stratum of the surrounding element in immediate contact with their surface. Here also they are seen on the mucous lining of the alimentary canal; they are early developed on the mantle and branchiæ of the embryos *in ovo*, and serve, for a time, as natatory organs in the young when hatched; and by the continuance of their action on portions detached from the body, they exhibit the same independence of volition as in other classes.

A transition from the branchiated to the pulmonated gasteropods is effected by the naked, amphibious, marine *onchidium*, in which, besides about twenty pairs of small

dorsal ramified branchial tufts, a distinct pulmonary sac, lined with vascular network, is observed, opening by a single spiracle, above the anus, on the median line, at the posterior end of the body; and both kinds of organs exhibit rhithmic respiratory movements of dilatation and contraction, in their respective elements. Some pulmonated gasteropods, breathing solely by lungs, live in the fresh waters, as *lymnæa* and *planorbis*, the exterior surface of whose body, and the mucous lining of the alimentary canal, are covered with vibratile cilia, as in the branchiated marine species; others are terrestrial, and testaceous, as *helix*, or naked, as *limax*, and these likewise breathe solely by means of a large single pulmonary cavity placed in the middle of the back, and opening by a single small round spiracle on the right side, near to the head. The interior surface of this sac is highly vascular, from the numerous large reticulate branches of the pulmonary arteries and veins there distributed; the aerated blood is transmitted to the auricle and ventricle, to be sent through the system, as in other mollusca; and the external aperture of the respiratory organ is here approximated to the anus, as in *onchidium*, and as these two passages are in most of the internal forms of respiratory organs of invertebrata. And thus, in the air-breathing gasteropods, the highest pulmonated invertebrata, the lungs already form a circumscribed cavity, extended along the middle of the back, with one tracheal opening, as the air-sac of fishes and the embryo lungs of all higher vertebrata.

All the *pteropods* are marine, branchiated, swimming mollusca, with a closed cavity of the mantle necessitating an external disposition of the branchiæ, and whose naked surface, or extensive palleal fold enveloping a thin shell, may assist in the aeration of the body. The branchiæ of the small naked *pneumodermon* form two considerable crescentic laminated organs extending freely from the surface of the mantle at the caudal extremity of the body. In the testaceous *hyalea*, they form an elliptical ring of branchial laminæ disposed on the back, between two folds of the mantle, and the lateral apertures of the shell appear to transmit the respiratory currents to this open cavity of the mantle. In *clio* and *cimbulia*, the natatory fins, developed from the sides of the neck, appear to support, on their striated or laminated

surface, the branchial vessels destined for the aeration of the blood.

The *cephalopods* are also entirely marine and branchiated mollusca, but with the palleal cavity open anteriorly, and the branchiæ, symmetrically developed on the two sides, are suspended by peritoneal and muscular folds along the dorso-lateral part of the abdominal cavity. The respiratory currents enter by the anterior lateral valvular openings of the mantle, and after bathing the branchial laminæ, they escape from the palleal cavity by the median valved orifice of the syphon. The large respiratory cavity is separated from that containing the nutritive and generative organs, by muscular aponeuroses and folds of the peritoneum. The branchiæ have a pyramidal form, with the free apex directed anteriorly; they consist of numerous superimposed laminæ, diminishing in size anteriorly; and they support the trunk of the branchial artery along their fixed upper margin, and the branchial vein along their pendent inferior free border. There are two of these organs on each side of the body in the *nautilus*, consisting, as on the left side of the pectinibranchiate gasteropods, of a larger and a smaller branchia—the bilateral symmetry established in the cephalopods, and the median position of the syphon, allowing of the equal development of these organs on both sides of the body. In the *argonauta*, another testaceous form, there is but one branchia on each side of the palleal cavity, and the same structure is seen in all the naked cephalopods; these organs vary, however, in their relative magnitude, and in the number of laminæ of which they are composed, in different species. There are only about twelve laminæ in each branchia of *octopus*, about fifteen in *argonauta*, about forty in *sepia*, and as many as ninety are sometimes found in one of the long narrow branchiæ of *loligo*, the branchial laminæ being generally smaller and narrower in proportion to the increase of their number.

The branchial circulation is accelerated, and consequently the extent of respiration increased, by the force of the two lateral muscular cavities of the heart; and the arterialized blood is sent by the branchial veins to the median single ventricle, for distribution through the body. The branchial laminæ, supported each around a central cartilaginous hoop like the arches of the gills in fishes, and minutely subdivided into

smaller lamellæ, present an extensive surface for the branchial vessels; and the currents are directed over them, as in fishes, by the rhythmic contraction and expansion of the surrounding parts. The loose valvular margins, extended from the broad base of the syphon, allow of the free ingress, and check the egress of the respiratory currents, by the sides of the palleal opening; and the valvular fold, directed forwards, in the canal of the syphon, prevents the entrance of the water by that passage during inspiration: so that there are already two lateral and one median opening employed in the respiration of cephalopoda, as of fishes, although the currents here take an opposite direction; and the bilateral symmetry of the respiratory organs, perfectly established throughout this class, accords with the numerous other approximations of the cephalopods to fishes, and to the vertebrated subkingdom.

FIFTH SECTION.

Respiratory Organs of the Spini-Cerebrated or Vertebrated Classes.

The higher vertebrated classes, like the entomoid classes of articulata, are mostly composed of air-breathing animals, the high development and activity of all their organs requiring this more effective mode of respiration; but the lowest vertebrata, like the lowest invertebrated tribes of every subkingdom, are limited to an aquatic respiration, in accordance with their simpler structure, and the diminished energy of all their functions. The blood is always propelled through the respiratory organs by the contractions of a muscular ventricle, and these organs always communicate directly with the cavity of the mouth, through which the respiratory currents, whether of air or water, are chiefly conveyed. As in most of the invertebrata, the respiratory organs are here always placed near the heart, but their openings are never approximated to the anus, as they most generally are in the molluscous classes. The branchiæ of vertebrata are always double and symmetrical, like those of the cephalopods, the highest of the invertebrated classes; and the pulmonary organs, which are sometimes single as in fishes, and even un-

symmetrical as in ophidia, are here always placed in the dorsal region of the trunk, as in the highest pulmonated mollusca. Some vertebrata, as the lowest fishes, are exclusively branchiated; others, as reptiles, birds, and mammalia, are exclusively pulmonated; others pass, by development, from the one mode of respiration to the other; others remain pulmo-branchiated, or truly amphibious, through life. But the temperature of the blood, and the energy of the muscular organs, directly correspond, in all, with the extent and activity of the respiratory system.

Although thus elevated in the scale, the respiration of *fishes*, like that of the lowest worms, is only aquatic and branchial; but in order to render this mode of respiration as effective as possible, the surface of these aquatic organs is here greatly extended, the surrounding element is rapidly renewed on their exterior, the whole blood of the system is sent through them for aeration, and its velocity is accelerated by the entire force of the heart. The respiratory organs of fishes consist of variously formed gills, attached to osseous or cartilaginous branchial arches, extending from the sides of the os hyoides upwards to the sides of the cranium. In the osseous fishes, there are four of these branchial arches suspended, free and moveable, under a wide opercular covering on each side of the neck. The branchiæ consist of numerous small, flat, tapering, cartilaginous laminæ, approximated closely to each other, bifurcated at their free ends, or cleft to their base, and arranged in a regular series, like the teeth of a comb, over the whole exterior convex margin of each branchial arch.

Over the very extensive surface presented by these innumerable, free, pendent laminæ, the whole venous blood of the system, sent from the heart and bulbus arteriosus, is conveyed by the minute ramifications of the branchial artery. The water inhaled by the mouth, is conveyed backward by an act like deglutition, and escapes on each side, between the separated branchial arches, and over all the vascular laminæ of the gills; and thus the venous blood of fishes is oxygenated, and decarbonized, and furnished with nitrogen for the gaseous secretion of their air-sac. Vibratile cilia have been detected both on the external and internal mucous surfaces of fishes. Some fishes are observed to swallow atmospheric air, to be conveyed through the

ductus pneumaticus, to the air-sac, or to aerate the vascular mucous lining of their intestine. As the great artery proceeding from the heart of fishes is entirely subdivided into branchial capillaries, and leaves no pervious anastomosing trunk communicating with the veins, as in amphibia, all the species are necessitated to retain permanently the aquatic character of the earliest tadpole state, incapable of undergoing metamorphosis by the absorption of the branchiæ. The trunks of the branchial veins returning the arterialized blood to the descending aorta, occupy the bottom of the marginal concavities of the branchial arches; the branchial arteries are exterior to them in these grooves; and in each small leaflet of the gills the arterial twig occupies the inner margin, and the returning vein the exterior edge.

The number of branchial arches varies in fishes, as in amphibia; in some plectognathi, as the *diodon*, there are only three pairs of gills; there are three pairs in the *lophius*, with the rudiment of an anterior fourth pair; most osseous fishes present four complete pairs; several present the rudiment of an anterior fifth pair; and a greater number is seen in many of the cartilaginous fishes. In the operculated fishes, whether osseous or cartilaginous, there are only two branchial openings, one on each side of the pharyngeal cavity; in the long cylindrical *gastrobranchus*, likewise, there are but two small round branchial openings, which are the terminations of two common lengthened canals, which receive the whole of the branchial currents, and convey them to the surface. In the sturgeon, the chimæra, and the spatularia, though cartilaginous fishes, the branchiæ are free at their margins, with a single opercular opening on each side of the neck; in the rays and sharks, where there is no free operculum, there are five narrow transverse openings on each side; and the outer edges of the branchiæ are fixed to the integuments between the several openings; so that the inhaled water is divided into five streams, passing over the surfaces of all the separate gills. In the *lampreys*, also with fixed branchiæ and without a free operculum, there are seven of those separate branchial cavities on each side, with as many small round openings, through which the respiratory currents pass to and fro, as in the lateral respiratory sacs of a leech or a worm. In place of the usual pectinated gills seen in other osseous and cartilaginous fishes, the lopho-

branchiate species, the *syngnathus*, *pegasus*, and *hippocampus* present a regular series of ciliated filamentous tufts, disposed along all the branchial arches, and much resembling the ramified branchial tufts of many gasteropods and annelides; these filaments are free at their ends, concealed in a branchial cavity, and communicate externally by a single operculated opening on each side, as the gills of other osseous fishes. In the *heterobranchus anguillaris*, there are also small accessory ramified branchial tufts, in addition to the usual laminated gills.

Besides the ordinary internal, covered, laminated branchiæ, many cartilaginous fishes, as the rays and sharks, and some osseous fishes, present, in the fœtal state, long, external, simple, branchial filaments, continuous with the internal laminæ of the permanent gills, and hanging down free from the sides of the exterior branchial openings. These deciduous, exterior, branchial filaments are lost in the fœtus of the rays and sharks, before they escape from the ovum; and in the osseous fishes, where they have been observed, they disappear by absorption at a very early period of fœtal life. In watching the development of the permanent branchial apparatus of fishes, the outer surface of the neck appears, at an early period, to have no branchial openings; but there are soon after formed five small separate holes on each side, even in the operculated osseous fishes. The branchial arches at length make their appearance, and the minute constituent laminæ of the gills begin to bud out from their edges. The laminæ increase in number, in extension, and in firmness of texture, and hang free from the sides of the neck; the opercular apparatus now begins to be developed, and by the gradual extension of its branchiostegous membrane and rays, the branchial organs are covered and concealed.

Most fishes have an air-sac in the abdomen, extended longitudinally under the vertebral column, exterior to the peritoneum, and containing a gaseous secretion, differing in its constitution from atmospheric air. The air-sac is most developed in species which frequent, or feed at the surface of the water, and is least developed or wanting in those which lie at the bottom or burrow in mud; its secretion contains a larger proportion of oxygen in the powerful predaceous fishes of deep seas, and nitrogen predominates in the feebler

species which frequent shores and shallow waters. Being developed, like the lungs of higher animals, from the alimentary canal, the air-sac of fishes generally communicates with the œsophagus or stomach, by means of a short trachea or *ductus pneumaticus*; in some, however, this tracheal communication becomes completely obliterated, and the sac remains an isolated, closed cavity, filled with its gaseous secretion, as in the xiphias. It is often provided with distinct muscular bands for its compression, and when largely developed, it is often capable of producing sounds, either under water as in pogonias, or in the air as in trigla, but there is yet no adaptation of laryngeal cartilages for systematically vocalizing these sounds.

The air-sac of fishes presents great diversities of general form, as well as of extent of development, being sometimes a single simple elongated sac, or provided with tubular or ramified appendices, or divided into sacculi by transverse constrictions, or symmetrically divided into two lateral cavities like the lungs of higher animals, as seen in several of the plectognathi. The highly vascular glandular organ, which secretes the gaseous contents, is most developed and distinct where there is no ductus pneumaticus, and is generally imperceptible where that tracheal canal exists. The air-sac is supplied with branches from the pneumogastric nerve, like the lungs of higher vertebrata; like the lungs of tritons, water-snakes, turtles, and other aquatic pulmoniferous vertebrata, this sac assists in poizing the body in that dense element; and it often communicates with the organ of hearing, like the respiratory passages of higher animals. In the herring, the long fusiform air-sac communicates by a narrow ductus pneumaticus, with the fundus of the stomach; in the sturgeon it opens by a short wide duct into the cardiac portion of the stomach; in the diodons, which inhale air at the surface of the water, and thus render their body tense and buoyant, the large air-sac communicates with the anterior portion of the œsophagus. In rays, frog-fishes, flounders, lampreys, and many others which lie at the bottom of the water or reside in mud, there is no air sac developed. The tracheal duct of many fishes already receives atmospheric air, sometimes pure, and sometimes derived from the inspired water, as that sent into the tracheæ from the minute openings of the branchial apparatus of some

aquatic insects in the larva state; it is still membranous, like that of a proteus, or of a lepidosiren; generally it is single, as in most higher vertebrata, but is sometimes double, as it is in many chelonia; and in some fishes it opens as high as the pharynx like the trachea of other vertebrated classes.

Thus, while the conditions of the branchial and pulmonary organs of fishes present a perfect adaptation for the dense element they are destined permanently to inhabit, they have many analogies with the forms of the gills and air-sacs of mollusca, and other invertebrated tribes, and also the closest affinities with the deciduous and permanent respiratory organs of the amphibia next above them in the scale. In the successive development, and in the different permanent forms of the branchial subdivisions of the great aortal trunk issuing from their single ventricle, they exhibit the embryo conditions of this vessel in all the higher vertebrata; and in the various conditions of their air-sac and ductus pneumaticus, they imitate the embryo forms of the pulmonary organs in all the higher air-breathing classes.

The *amphibious* animals breathe at first, like fishes, by means of branchiæ; their air-sac is double, and is now more obviously subservient to aerial respiration, and they respire also by the entire surface of their naked, sensitive, and vascular skin. In the earliest condition of the tadpole, when the whole body is covered with vibratile cilia, small ciliated branchial filaments are seen extending from the sides of the neck, which produce currents of water over their surface by the action of their minute vibratile organs; and in this first external filamentous condition of the gills, they may be compared to the earliest deciduous external branchial filaments seen in many cartilaginous and osseous fishes. Around the margin of each of these short simple primary filaments, a single capillary blood-vessel extends; and by the successive formation of loops on this vessel, small ramifications originate and develope along the sides of each branchial filament—each branchial ramification having only a single capillary blood-vessel around its margin. Before the development of the pulmonary organs and the left auricle, the venous blood of the system in the tadpoles of amphibia, is sent through a bilocular heart, a bulbus arteriosus, and branchial arteries, as in the class of fishes; and in many of the larvæ of am-

phibia, as in the fishes, the primary free external filiform branchiæ are changed at a later period, for more circumscribed internal forms of these organs.

In the perennibranchiate amphibia, the branchiæ are retained, along with the pulmonary organs, through life; and in the caducibranchiate species, every trace of these organs becomes absorbed, and the respiration is effected in the adult state solely by the developed pulmonary cavities. The branchiæ here, as in fishes, are supported by cartilaginous arches connected with the posterior cornua of the os hyoides, and vary in number and form and relative development in different species; there are three or four of these arches on each side, composed each of one or more pieces, presenting often rudimentary teeth along their inner margin, supporting the free pendent gills along their outer convex edge, and protected anteriorly by a rudimentary cutaneous operculum. The branchiæ are retained longer in the larvæ of the urodelous forms, as the tritons, than in those of the anurous species as the frogs and toads ; and the branchial arches, in both tribes, during the metamorphosis, are gradually absorbed with the gills, so as to leave only the os hyoides with its curtailed cornua, in the adult state. In the external forms of the branchiæ, the ciliary currents are directed outwards over their surface to the free ends of the branchial laminæ, and the ciliary actions continue on portions of the gills, and on portions of the general skin, detached from the body, as the ciliary actions in other classes of animals.

The branchial arches of amphibia, as of fishes, generally four in number, do not always support effective respiratory gills; thus there are four branchial arches in the triton, and only three of these are furnished with gills; the posterior arch is that most generally destitute of branchial laminæ. There are likewise only three gills on each side in the siren, the proteus, and the oxolotus, where they are permanent in the adult state, and hang freely exposed from the sides of the neck; there are four gills on each side in the larvæ of anurous amphibia. Muller observed distinct branchiæ within a round opening, a line in width, on each side of the neck, in the larvæ of *cæcilia* already three inches long. The branchiæ are not composed of closely approximated lanceolate parallel laminæ as in fishes, but are here cutaneous penniform ex-

tensions, with a middle stem from which the soft ramified compressed filaments or laminæ hang free on each side.

By the movements of the lower jaw and os hyoides, the respiratory currents of water are directed inwards by the mouth, and outwards by the lateral branchial openings, as in fishes; and the stratum of water in contact with the surface of the external pendent branchiæ, is further renewed by the constant vibration of the minute cilia closely covering their whole exterior, as in the branchiæ of inferior classes. Although the branchial laminæ are not here fixed at their outer ends as in cyclostome and in plagiostome fishes, the number of exterior lateral branchial openings varies in different species, there being but one on each side of the neck in the larvæ of anurous amphibia, two in the proteus, three in the siren, and four in the triton. The branchiated period of the larvæ of *salamandra* is commenced within the oviducts of the female, and that of *pipa* is passed within the cells of the parent's back; in most others it is passed in the water, where the ciliary action of the entire naked cutaneous surface of the body, compensates for the imperfect development of other respiratory organs. Even in the adult state, frogs have lived thirty hours after the entire removal of their lungs, breathing then solely by their naked cutaneous surface, which is also their sole respiratory organ during months of hybernation, immersed in mud under water during winter.

In the proteus, the axolotus, and other amphibia which permanently retain the gills, there are two long membranous respiratory air-sacs, rudimentary lungs, extending, like the air-sac of fishes, far backwards into the cavity of the abdomen, above the other viscera, but freely moveable in the cavity of the peritoneum, and covered with that serous membrane. The small pulmonary arteries descend from the posterior branchial trunks of the aorta, their ramifications form a close network over the entire surface of the pulmonary sacs, and the aerated blood is returned by the pulmonary veins to the small left auricle of the heart. The lungs are here simple sacs, without internal cells, and they communicate with the pharynx by thin membranous smooth ductus pneumatici, or tracheæ, still nearly destitute of all cartilaginous rings or annulated appearance. This simple condition of the lungs and trachea is seen also in the *triton* in the adult state, but is only a transient condition of these organs in the larvæ

of *salamandra* and of the anurous amphibia. These organs are much more developed in the adult frogs, toads, and salamanders, where the lungs are capacious, broad, short, entirely subdivided internally into large cells, and more confined to the anterior portion of the trunk.

Along the sides of the short membranous trachea, both of the caducibranchiate and perennibranchiate amphibia, irregular longitudinal continuous tracheo-laryngeal patches of cartilage are seen extending, and these shoot out transversely small processes, which in higher animals become, by absorption, distinct isolated tracheal rings. The upper portion of these two lateral tracheo-laryngeal cartilages already become separated to form arytænoid cartilages in all the amphibia, as shown by Henle, and the rudiments of cricoid and thyroid cartilages are generally perceptible, thus composing a rudimentary larynx or organ of voice; the lower portions, descending along the lower sides of the trachea, become broad, and their lateral processes almost divided into distinct transverse pieces, the rudiments of tracheal rings, in the *salamanders*, and they are more distinct in the *pipa* and in the *cæcilia*. In the frog, the small *cornicula laryngis* are already detached from the ends of the arytænoid cartilages, as in mammalia.

The larvæ of frogs and other caducibranchia, breathe for a time, both by lungs and branchiæ, and by the naked surface of the skin, as the perennibranchia; the branchiæ of the frog are early withdrawn into a capacious pharyngeal cavity, communicating externally, as in cartilaginous fishes, by small lateral cervical openings, which soon close up entirely, and the cavity remains capacious in the male, for the production of the croaking sounds. As the ribs, when present, are ineffective for respiration in amphibia, the lungs are gradually filled with air by the successive movements of the os hyoides and pharynx, as in chelonian reptiles where the ribs are entirely immoveable, hence they are unable to breathe when the mouth is forcibly kept open. The higher amphibia thus exhibit remarkable metamorphoses in their respiratory organs, commencing their career while yet in the ovum, with cutaneous vibratile cilia, like the respiratory organs of the lowest radiated animals, then acquiring external branchial tufts like those of the lowest worms or gasteropods, then internal covered branchial laminæ like those of fishes, and at length internal cellular lungs like those of the higher vertebrata.

The *reptiles* breathe solely by means of pulmonary cavities, no branchiæ having been hitherto detected in any condition of animals higher than amphibia, and the thick scaly coverings of serpents, saurians, and chelonians, preventing respiration through their skin. The form of the lungs of reptiles as that of their other organs, accords with the general form of the body, being long simple sacs in the serpents, broad cellular organs expanded over the whole dorsum of the trunk in chelonia, and approaching nearer to the mammiferous type in the higher sauria. The want of bilateral symmetry in the pulmonary organs, often produced in quadrupeds by the sinistral position of the heart, is greater in serpents than in all other vertebrata, as they are here sometimes developed only on one side of the body, and that the right, on which side alone they exist in the highest pulmonated invertebrata, the air-breathing gasteropods, and on which side they are largest in the mammalia. In many saurians also the right lung is much larger than the left. These proportions of the two lungs, however, appear to be reversed in some ophidian reptiles, without the law of this variety being apparent.

The lungs of *serpents* are generally composed of two unequal, long, narrow, cylindrical or fusiform sacs, extending far back in the cavity of the abdomen, above the other viscera, surrounded with the serous lining of that cavity, without internal cellular divisions, excepting at the dorsal portion of their anterior end. In different species of coluber, typhlops, and vipera, the lung of one side only is developed, and in other genera, as boa and python, they are developed nearly equally on the two sides. They communicate by a long narrow, single, firm, annulated trachea, surrounded by distinct, though incomplete rings, with the back part of the tongue, where the larynx already presents the arytænoid, cricoid, and thyroid cartilages, and is sometimes furnished with a distinct epiglottis, as shown by Henle in the large *crotalus durissus*. The annulated marking of the almost membranous trachea, is sometimes, as in python, continued perceptibly over the long cylindrical pulmonary sacs. On opening the lungs of the boa or python, as in most other ophidia, a beautiful cellular and highly vascular appearance is presented in the interior of the upper and back part of these organs, somewhat resembling the interior polygonal cells of the second stomach of ruminantia, and

consisting of innumerable delicate septa of small open air-cells extending into that part of the cavity, like the embryo air-cells in all higher animals, and greatly extending the surface over which the pulmonary capillaries are spread. The rest of the lung, on each side, presents a continuous simple internal cavity, with smooth parietes, covered by the reticulate ramifications of the pulmonary vessels. A larger quantity of air is taken into the lungs of serpents and other reptiles, especially of aquatic species, than can be effectively employed in oxygenating their blood, and this may give tension to the body to aid their progressive movements, or buoyancy and lightness for swimming, or resistance to assist in the generative and fecal discharges, or the means of longer suspending respiration when required, or of increasing and prolonging their defensive hissing sounds.

Although distinct branchiæ are not developed in any of the true serpents (the naked serpents or *cæciliæ* being now properly removed to the class amphibia) the great branchial trunks of the aorta, and the branchial openings on the sides of the neck, are seen in the embryos of these animals, as of all the higher vertebrata, and of man. In the embryo of the *python*, Meckel detected three branchial openings on each side of the neck; in the embryo of the *coluber natrix*, Baer observed the aorta, at its exit from the heart, divided into four pairs of branchial arteries; and similar observations have been made by Rathke and others.

In the *saurian* reptiles, as in the ophidians, the ribs being moveable, the respiration is chiefly effected by the action of the intercostal muscles, without the aid of a diaphragm, which does not yet separate the thoracic from the abdominal cavity. The lungs of sauria are more equally developed on the two sides of the body than in serpents; they generally extend far back into the abdomen, their lower and posterior part is often scarcely divided into cells by any internal partitions, and their upper and dorsal portion is minutely cellular. In many of the higher species, however, as the lizards and crocodiles, the lungs are entirely subdivided internally into small cells, and they are confined to the anterior thoracic region of the trunk, as in mammalia. Each lung of the *scincus officinalis* forms a single continuous cavity, but the entire inner surface of the parietes is cancellated by small projecting reticulate septa, like the developing peripheral cells

in the embryo lungs of birds and mammalia, and the cancellated portion of the lungs of most serpents. The upper and dorsal part of the lungs of the chamælion are, as usual in the sauria, minutely cellular, lower in their cavity the cells become much larger, and at their lower extremity, the internal septa have entirely failed, and the ends of the lungs are prolonged over the whole fore part of the abdominal viscera, in the form of long free saccular digitations, forming lengthened, undivided, continuous cells. The long sacs extending free over the whole abdomen from the cellular lungs of the chamælion, are analogous to the abdominal air-cells of birds prolonged from the terminal ends of their bronchi; but where the diaphragm is completed, in mammalia, the pulmonary organs are entirely restricted to the thoracic division of the trunk, and are everywhere minutely divided internally by the ramifications and cells of the bronchi, to increase the extent of surface for the distribution of blood-vessels.

A rudimentary diaphragm is already seen in the crocodilian reptiles, extending in radiating peripheral muscular bands over the inferior part of their minutely cellular and entirely thoracic lungs; the rudimentary diaphragm is seen also in the chelonians, and in many birds, especially in the ostriches. In the gecko fimbriatus, as in the emeu of New Holland, there is a wide separation of the rings of the trachea, and a membranous portion, capable of distension, passing between the widely separated ends of the rings, about the middle of the course of the trachea. In different species of chamælion, there is a considerable round membranous laryngeal sac, opening into that canal by a transverse valvular slit, between the lower margin of the larynx, and the upper margin of the first tracheal ring, on the fore part of the neck. The transverse valvular margins of the two cartilages bounding the slit, project into this laryngeal sac, like a rudimentary epiglottis, and the cavity of the sac is partially divided by a median crescentic septum extending inwards from its upper and anterior part. The anterior tracheal ring is complete in the geckotida, but is still incomplete in most saurian genera; the anterior tracheal rings are incomplete in the crocodilians and most chelonia, but gradually become united towards the bronchial end of the trachea.

The branchial openings on the sides of the neck, and the subdivision of the aortal trunk into regular pairs

of lateral branchial arteries, have been often observed in the embryo of the common *lacerta agilis*; five pairs of branchial arteries were perceived by Baer; three branchial openings have been observed, at the same time, on each side of the neck, in saurian, as in ophidian reptiles; a smaller fourth opening makes its appearance at a later period. In the substance of the first or most anterior of these pharyngeal folds, thus formed by the successive fissuring of the outer serous layer of the neck, in the embryo of vertebrata, are developed the two lateral portions of the lower jaw; in the second fold, are formed the cornua of the os hyoides; and in the succeeding folds are developed, in branchiated animals, as fishes and amphibia, the true branchial arches and gills for aquatic respiration.

The lungs of *chelonian* reptiles still extend over the whole dorsal part of the trunk as far as the pelvis; they are fixed by the pleura to the ribs, which also separates them from the cavity containing the digestive and generative organs; they are symmetrically developed on the two sides, largely cellular internally, very capacious, and still composed of a single distinct undivided lobe on each side. The large-celled capacious lungs of turtles, expanded over the whole dorsal region of the trunk, serve most advantageously to poise their heavy body and its members while swimming, or floating asleep in the water, like the air-sac of fishes, or like the extensive pulmonary organs of birds, which poise their suspended heavy parts while swimming in the light air. The extent of respiration corresponds, not with the quantity of air taken into the body of an animal, but with the extent of surface over which the aerated blood is spread, the rapidity of the blood's course over that surface, and the frequency of the renewal of air in the pulmonary organs. The small, but minutely subdivided cellular lungs of a rabbit, present a much more extensive surface for the distribution of pulmonary blood-vessels, than the capacious lungs of a turtle ten times its size; and although the quantity of air taken in by the quadruped is less, it is entirely employed in effecting the aeration of the blood, and hence its higher temperature, activity, and general development. As the ribs of chelonia are immoveable, the lungs fixed to their interior, and the diaphragm consists only of a few muscular bands extending

over their inferior surface, inspiration is effected, as in frogs, by the movements of the os hyoides and the pharynx, and expiration chiefly by the abdominal muscles; and from the fixed condition of the osseous elements surrounding the trunk, the resistance of the distended capacious lungs is necessary to assist in all discharges from the body.

From the length and movements of the neck, the trachea is generally elongated in fresh water and marine chelonia, as in birds, and is surrounded, as in them, with complete cartilaginous rings; it sometime divides, in the land species, into two bronchial branches nearly as high as the larynx, one of which proceeds along each side of the neck, protected from compression during the retracted state of the head, by entire tracheal rings. The epiglottis is only a membranous fold across the anterior part of the opening of the glottis, but the rudiments of the vocal chords extend further into the larynx, and are more developed in chelonian than in other reptiles. The vibratile cilia, which line the nasal and buccal passages, the pharynx and œsophagus, and the larynx, trachea, and interior of all the pulmonary organs of amphibia and reptiles, are most remarkable for their tenacity of life in the lungs of chelonia, where they have been observed in activity for several weeks after death, and on portions detached from the body, even when putrefaction had commenced. The two bronchi of chelonia, enter the inner portion of their corresponding lungs, and in traversing the whole extent of these organs, they open as in birds, by numerous lateral perforations, into the large saccular cells of the lungs, which are regularly disposed in outer and inner series, as shown by Bojanus in the *emys*.

In *birds*, as in insects, the inspired air is transmitted through almost every part of the body, and the blood sent through the branches of their systemic vessels is freely aërated, as well as that contained in the vessels of the lungs. The pulmonary organs of birds present a form intermediate between those of reptiles, extended through the abdominal cavity, and those of mammalia, confined to the thoracic portion of the trunk. The large cells prolonged from the ends of the bronchi, still reach the posterior part of the abdomen, like the lungs of fishes, amphibia, and reptiles; and as the lungs are not collected into the anterior part of the trunk,

as they are in quadrupeds, there can yet be no muscular septum or diaphragm separating its cavity into a thoracic and an abdominal portion.

As in most reptiles, the pulmonary organs of birds are composed of an anterior minutely subdivided cellular portion, and a posterior largely sacculated part, but slightly partitioned by internal septa, and contained, as usual in oviparous vertebrata, in the same cavity with the digestive organs. The highly vascular parietes of the abdominal air-sacs, or enlarged pulmonary cells, covered with peritoneum, and lined with the ciliated mucous membrane of the lungs, extend forwards and backwards around the chylopoietic viscera, and reach in every direction beyond the cavity of the trunk, as into the axilla, the neck, the vertebræ, and the bones of the extremities. Their interior is partially subdivided by imperfect septa, the first rudiments of all pulmonary cells, which begin to develop from the periphery; and they communicate by a few large round openings, on the inferior surface of the lungs, with the ends of the wide bronchial tubes, which traverse these organs, with little subdivisions, and nearly in a straight course.

These air-sacs, and their free communications with the lungs and trachea, were familiar to Harvey, who regarded them as the principal parts of the lungs of birds, and who found their bronchial openings in the ostrich so wide as to admit the finger. The air-sacs are generally in contiguous pairs, separated by a median septum, and opening each by a distinct foramen into its corresponding lung. One large cell on each side extends forwards, under the sternum and coracoid bone, supplying with air the bones of the shoulder and arm, enveloping the heart, the bronchi, and the inferior larynx, and extending into the axilla. Another extends into the neck above the clavicles, forming various enlargements in different species, on each side of, or beneath the crop; another beneath the sternum, extends also behind the heart and œsophagus, to the vertebræ of the neck, thus enveloping the great vascular trunks of the heart. Another large pair, sometimes subdivided into an anterior and posterior compartment, extends backwards along the dorsal and lateral parts of the abdomen, enveloping most of the viscera, forming air-sacs in the pelvis, and extending into the bones of the legs.

The bones of the head, neck, trunk, and extremities, are thus

permeated with air from the pulmonary organs, to a variable extent in different tribes of birds, according to their power of flight, and their necessity for extensive aëration of their fluids. As these cells and cavities are filled with heated air from the lungs, the whole body is thereby rendered more light and buoyant for progression through the colder and denser external medium. The highly vascular entosteal lining of the bones, like the vascular mucous lining of the great air-sacs of the trunk, contributes to the aëration of the systemic blood; and the extensions of the air-sacs thus penetrate the tissues of the body, as they do in insects. When the trachea is tied, birds can still inhale air, and inflate their cavities, by the broken ends of the humerus or femur, and when the bones of the extremities are fractured in flight, they are thus quickly precipitated to the earth. The bones which receive air in birds, have a more dry, white, and less oily appearance, than those which permanently preserve their marrow. The air admitted into the interior of the bones during the development and growth of birds, causes, to a variable extent, the gradual absorption of the thin serous marrow, which originally occupied all their cavities.

The proper cellular lungs of birds, like those of chelonian reptiles, are excluded from the peritoneal cavity, and bound by cellular tissue to the inside of the ribs and the sides of the dorsal vertebræ, being covered only on their ventral surface with peritoneum, which is prolonged also from the large bronchial apertures over all the abdominal air-sacs. They were considered by Bartholinus as fixed to the upper and dorsal region of the trunk, in birds, to balance their body in flight. They consist of a single long, flat, nearly triangular, undivided lobe on each side, and have a more light florid red colour than in other vertebrata; their minute cells have a parallel and methodical arrangement, around the bronchi, and freely communicate. The bronchi, thin and membranous, with annulated markings on one side, traverse chiefly their ventral and median portions, dividing in each lung, into about seven branches, perforated in their dorsal aspect with numerous foramina, leading to the minute pulmonary cells, and terminating below in the wide oblique orifices of the great air sacs. Their narrow, thin, inferior, and outer margins are traversed by the radiating peripheral muscular bands, composing the rudimentary diaphragm, as in saurian and chelonian reptiles, and by their thin tendinous expansions;

their interior is more uniformly cellular throughout than in reptiles, and the cellules are larger than in mammalia, giving a light spongy texture to these organs, which occupy a comparatively small space in the alvi-thorax of birds. Meckel found the lungs of an emaciated eagle to weigh only $\frac{1}{170}$ of the entire carcase, and those of an equally spare heron $\frac{1}{137}$; they are proportionally largest in the singing birds, and least in the strutheous and other heavy species.

The trachea, like the neck, is necessarily lengthened in this class, and the tracheal rings, like the cartilages of other parts of their body, are generally ossified, and thus preserve a free passage during the various contortions and pressures to which this part is exposed. Surrounded with entire ossified rings throughout its course, it descends along the left side of the œsophagus and crop, into the cavity of the trunk; commencing above in a larynx, simple and uniform in structure, and much resembling that of chelonian reptiles, it terminates below the clavicles in a complicated osseous moveable apparatus, the inferior larynx, for modulating the vocal sounds; here the trachea bifurcates to form the two soft and partially annulated bronchi, which, without any previous subdivision, penetrate the ventral surface of the lungs, a little behind their thick anterior margin. The trachea is often lengthened by convolutions at its lower part in aquatic birds, as swans, cranes, geese, pintados, demoiselles, and spoonbills; the larynx and tracheal rings, are cartilaginous in the strutheous and some other birds, as in mammalia. The canal of the trachea, though commonly cylindrical, is often varied, especially in the male, by constrictions and dilatations in its course, as in *mergus*, *anas*, and other palmipedes, where the rings continue complete around the dilated parts. The tracheal rings are sometimes incomplete and open at the dilated part, as first shown by Fremery, in both sexes of the emeu of New Holland, where they leave a free membranous tracheal pouch a little above the sternum. The rings are often sutured on one side; they are remarkably destitute of bilateral symmetry in cranes and some other wading birds; and the lower part of the trachea is sometimes divided internally by a longitudinal membranous septum, as in *procellaria* and *aptenodytes*. For the retraction of the long trachea of birds, it is commonly provided with a superficial and a deep-seated pair of retractor

muscles, the *ypsilo-* and *sterno-tracheales*, which are sometimes of great length. The tracheal differences of the sexes, and of nearly allied species, affect, also, the inferior larynx, and are greater in birds than in any other classes; and they are sometimes connected with differences of the voice. The superficial retractor muscles are often wanting, especially in wading birds, as in the long necked phœnicopterus, where there are, at least, three hundred and fifty tracheal rings; a number not surpassed in any other bird.

The inferior larynx of birds, like other vocal organs, is a mere accessary development of the trachea, placed on that tube to take advantage of the elasticity of the transmitted air, for the purpose of producing sounds, and thereby giving audible expression to the inward feelings. The ordinary and most convenient seat of these sounds, the superior larynx, is developed in birds, as in other air-breathing vertebrata, and its vibratile margins can partially vocalize the transmitted air, like the larynx of many reptiles, to which that of birds is most closely allied in structure. But the great length, and the varying dimensions of the trachea, the unsuitable form of the tongue and buccal parietes of birds for modulating sounds, and the demand for extensive vocal intercourse in this class, necessitate the development of a new organ of voice, an inferior larynx, placed nearer to the lungs and air-cavities. This inferior or bronchial larynx, situated at the bifurcation of the trachea, and involving the commencements of the two bronchi, consists of enlarged, ossified, often much altered and anchylosed, tracheal and bronchial rings, with great membranous interspaces. The lowest tracheal ring, by extending centrad before and behind, bisects its canal with an osseous septum; and the membranes of the interspace, by passing centrad from each side, form two free internal crescentic vocal ligaments. Two semilunar membranes also extend, in singing birds, from each side of the median septum, to meet the lateral folds, and complete the vibratile lips of these two rimæ; two simpler vocal folds, at the narrow membranous origin of each bronchus, are likewise added to this complex wind-instrument. There are five pairs of muscles for the various movements of the inferior larynx in singing birds; in parrots, where this part of the vocal apparatus is more simple, theree are thre pairs of muscles; in many rapaceous, grallato-

rial and other birds, with less power of modulating their sounds, there is but one pair of these inferior laryngeal muscles, and in the gallinaceous and a few other birds, there are no special muscles for the movement of the inferior larynx, distinct from the ordinary muscles of the trachea.

The superior larynx is still very simple in birds; it is much more uniform throughout the class than the inferior, and it more nearly approaches to that of reptiles, especially of chelonia, than to that of mammalia. The large thyroid cartilage forms the anterior part, and the entire base resting on the first tracheal ring, and its two lateral quadrangular pieces, often detached when ossified, have commonly been mistaken for the cricoid cartilages. These three principal constituent parts of the thyroid, remain united through life in swans, pelicans, parrots, ostriches, and some other birds, especially where they retain their primitive cartilaginous condition; but where they become ossified, the broad pentagonal anterior, and two lateral four-sided pieces, leave greater or less cartilaginous interspaces between them, which have impeded the identification of the laryngeal elements of birds. The rudiments of tracheal rings are generally seen at the base of the large middle anterior piece of the thyroid, indicating the mode of development and separation of the more perfect inferior rings. The thyroid pieces are disunited on the median line behind, though generally in contact; and on dissecting the inner and upper part of the anterior piece, the cartilaginous rudiments of the epiglottis, are seen extending upwards and inwards. In the storks and herons, the *processus epiglotticus* rises upwards broad, like that of an agama among the sauria, and is already ossified in these birds, like most of their tracheal and laryngeal parts. In many gallinaceous and other birds, the epiglottis is flat, thin, and flexible, like that of mammalia; and the most perfect forms of the epiglottis observed by Henle in the birds, were those of *sterna*, *rallus*, and *larus*, where it is detached from the thyroid cartilage, and extends free, flexible, and cartilaginous, into the pharyngeal cavity.

Between the posterior ends of the thyroid cartilage, in the angular space commonly left behind by the meeting of its edges, is situated the small cricoid cartilage of birds, of a quadrangular, or triangular form, often ossified, tapering

downwards, and supporting the arytænoid cartilages above, attached to each side of its free projecting margin. It presents a middle, and two lateral centres of ossification, sometimes separated from each other by vertical fissures, and is often partially attached to the basilar ring of the thyroid, and to the lateral quadrangular pieces of the thyroid, which has induced many to consider the whole of these pieces as forming together the cricoid cartilage of birds. The long, narrow, triangular, arytænoid cartilages, tapering forwards, broader, and united together behind, generally ossified, bound the rima of the glottis with their straight inner margin, and are attached to the thyroid by their outer edge. Though generally ossified, like the other laryngeal and tracheal parts of birds, the cricoid and other laryngeal cartilages remain soft, flexible, and cartilaginous in the strutheous birds, as in mammalia. The larynx and trachea are raised chiefly by the *hyothyrioideus* and the *thyriotrachealis* muscles; the laryngeal opening is widened by the *thyrioarytænoideus posticus* muscle, and is compressed by the *thyrioarytænoideus lateralis*, as in the higher reptiles. The muscles of the upper larynx of birds appear to be supplied chiefly by the superior laryngeal nerve, which protects the passage of the glottis, and the muscles of the lower larynx, or organ of voice, by the inferior laryngeal, or vocal nerve.

In the embryo of birds, the lungs appear as two small sacs or follicles, developed from the œsophagus or pharynx; their apertures coalesce and elongate, to form a tracheal duct, on the median plain; the interior parietes of these primitive pulmonary sacs, develope peripheral septa or follicles, to form the rudiments of their internal cells, which are arranged with great regularity, though subdivided and ramified, around the bronchial canals; and the membranous tracheal duct, or ductus pneumaticus, becomes cartilaginous, segmented, and divided into a distinct superior and inferior larynx, with a more simple intermediate, lengthened, annulated trachea. Before the branchial openings have formed on the sides of the neck, the integuments appear entire on both sides, and when the embryo is more advanced, three lateral passages are discovered on each side, leading into the cavity of the pharynx. They are seen in the chick on the third day of in-

cubation, and they continue open to the eighth. The aorta divides from its origin, into two great lateral arches, each of which subdivides into the five branchial arteries of its own side, which receive the entire blood of the heart. Between the second and third days of incubation, four pairs of branchial arteries are observed to be produced in succession from before backwards; and the first, or anterior of these pairs, has disappeared before the fifth pair of branchial arteries is developed, behind the others, on the fifth day of incubation. The same order of succession is observed in the development of the pairs of branchial openings in the neck, from the anterior to the posterior pair. The vibratile cilia are seen in active motion, on the mucous lining of every part of the respiratory organs of birds, from the openings of the nostrils and the interior of the eustachian tubes, to the minutest divisions of the bronchi, and the closed extremities of the great air-sacs extending through the trunk.

The respiratory organs of *mammalia* are confined to a distinct thoracic cavity, separated from the abdomen by a complete muscular and tendinous diaphragm; and as this function is not extended to their systemic vessels, as it is in birds, they manifest a lower temperature of the body, and a diminished energy of their muscular system, and of almost all their vital properties. The lungs here are covered on all sides with pleura, and float free in the cavity of the chest; they no longer communicate with abdominal air-sacs, or with the cavities of the bones; they are entirely divided into more minute cells, so as to present a more extensive respiratory surface than in inferior classes, and they are larger in the male than in the female sex. They are more minutely and equally divided into cells, and into lobes, and present a larger respiratory surface, and occupy a larger thoracic cavity, in the more powerful carnivorous quadrupeds, than in the feebler herbivorous tribes, where the more limited development of the respiratory organs is accompanied with a diminished energy of all their movements and functions. The contiguous minute terminal cells of the lungs appear to communicate with each other, like the ultimate tubuli of many other glands. The lung of the right side is generally larger than the left, from the sinistral position of the heart, especially in the higher mammalia and man, and

the number of lobes on each side generally corresponds with that of the primary divisions of the bronchi.

In the cetacea, they present the most firm compact texture, the largest cells, and the least division into lobes; they are also but slightly lobed in many of the ruminantia, pachyderma, and even chiroptera, and in some of the larger herbivora they present no lobular divisions on either side; thus approaching, in the lower mammalia, to the undivided condition of the lungs in birds. The bronchi ramify to a great degree of minuteness before ending in the small vesicles, or terminal air-cells, on the parietes of which the pulmonary capillary vessels are chiefly distributed. The mucous membrane, lining all the nasal passages, the eustachian tubes, the larynx, trachea, and bronchial ramifications, is covered with active vibratile cilia, as in inferior vertebrata, and which continue their active movements on detached portions, long after death. Although the lungs of mammalia do not extend beyond the cavity of the thorax, the air is admitted in some chiroptera, as first shown by Geoffroy in the *nycteris*, into large cellular sacs surrounding the trunk of the body, between the skin and the muscles, especially of the back and sides in the common *plecotus*, which assists in bracing the muscles, and probably in aeration, and lightens the body by the retention of heated air, as in birds. The air is introduced into these subcutaneous cells of the bats, by a small round aperture, provided with a sphincter, and situated at the bottom of each of the two cheek-pouches. The entrance to the respiratory organs in most aquatic mammalia, as seals and beavers, is protected by the valvular structure of the nostrils, which they can completely close against the water through which they move with rapidity; and a similar structure is seen in the nostrils of the camels, and some other ruminantia, to protect them against the drifting sands of the deserts. In several cetacea, as the porpise, the nostrils form two elongated moveable muscular sacs, as in some crocodilian reptiles, by extending which to the surface of the water, they can respire freely, while the rest of their body is entirely immersed.

The *trachea* of mammalia varies with the length of the neck, in the different species, and is generally shorter and more straight than in birds; it is nearly of equal calibre,

without convolutions or enlargements in its course, or an inferior larynx; it is frequently directed a little to the right of the œsophagus, and is closely surrounded with rings, for the most part incomplete on their posterior aspect, sometimes incomplete in front, as in many of the cetacea, and of a cartilaginous texture, though often becoming ossified in advanced age. It divides in the cavity of the thorax commonly into two, sometimes into three bronchial tubes, which again subdivide before entering the substance of the lungs. The bronchi often continue their cartilaginous rings, with their intervening fibrous structure, through their minuter divisions in the lungs. The posterior vacant spaces between the ends of the tracheal rings, present distinct transverse connecting fibres, and longitudinal fasciculi of fibres are seen passing between the margins of the successive rings. The tracheal rings are completed behind in the most diversified forms of mammalia, as in the long-necked ruminantia, and the short-necked cetacea, in burrowing rodentia, and in flying chiroptera, and probably relates to the extent of motion or pressure to which this part may be exposed by the living habits of the species. The trachea appears to be somewhat elongated and curved in the thorax of bradypus, as common in the feathered tribes to which they are so much allied.

The *larynx* of mammalia, like that of inferior vertebrata, is formed by the development and consolidation of tracheal rings, and presents the most complex and perfect form of this part, being formed on the anterior and lateral parts by the thyroid cartilage, on the posterior and inferior parts by the cricoid, and on the upper and inner part by the arytænoid cartilages. The *thyroid* cartilage, which meets behind in birds as well as in front, is always widely deficient on the back part in mammalia, where the interspace is occupied by the now greatly developed cricoid. The two posterior pieces of the thyroid of birds, as shown by the careful researches of Henle, have here coalesced with the cricoid, to compose a part of that cartilage, as the styl-hyoid bone of inferior quadrupeds separates from the os hyoides, and anchyloses with the temporal in man, to form a process of that bone. The posterior margin of the thyroid is extended downwards on each side, to form the narrow inferior cornu for the

attachment of the cricoid cartilage, and the same posterior margin is prolonged upwards to form a superior cornu for the attachment to the os hyoides. The thyroid cartilage is still sometimes divided vertically on the median plain, by a distinct suture, into two lateral halves, as it is in many of the reptiles; and although it no longer manifests a division into its primitive separate tracheal rings, the perforation for the inferior laryngeal artery is considered by Henle as indicating an earlier separation at that point. The thyroid cartilage of the ornithorhynchus is a small, simple, flat, arched piece, without either superior or inferior cornua, and its firm ligamentous connection with the hyoid bone, was supposed by Meckel to be a peculiar extension of the thyroid cartilage, embracing the œsophagus, in this animal.

The *cricoid* cartilage of mammalia, always most developed behind, where it rises upwards between the posterior edges of the thyroid, and tapering forwards, where it is often deficient, as in many carnivora and cetacea, is formed by the union of the small cricoid of chelonia and birds with the detached posterior, or lateral pieces of the thyroid seen in the latter class. It here commonly forms a complete ring, united though small in front, resting on the first tracheal ring, attached to the inferior cornua of the thyroid, and by a small vertical median ridge behind to the œsophagus, and supporting on its upper convex posterior articular surfaces, the two arytænoid cartilages. There are commonly two small round *interarticular* cartilages, discovered by Brandt, like sesamoid bones, between the upper edge of the thyroid and the articular surfaces of the arytænoid; these are largest and triangular in the hedgehog, and are transversely elongated in the vampire. Similar small *interarticular* pieces are also frequently found between the posterior and inner edges of the arytænoid cartilages, which in the ornithorhynchus, the opossum, and some other mammalia, are consolidated into a single piece on the median plain.

The two *arytænoid* cartilages preserve their elongated triangular form and their general connections, most constantly throughout the pulmonated vertebrata, being less extended longitudinally in mammalia than in birds. Resting by their grooved and smooth articular bases on the back part of the cricoid, and extending forwards, with their flat

inner margins parallel and approximated, they commonly present, at their tapering anterior ends, the small *capitula santorini*, which are attached to their apices by distinct articular surfaces, and ligamentous fibres. The *capitula* are merely continuous, curved, terminal processes of the arytænoid cartilages in the ruminantia and solidungula, as in the lower classes, and become distinct cartilages in the higher mammifera, where we observe also, for the first time, two small detached *cuneiform* cartilages lying between the folds of the mucous membrane, the *ligamenta aryepiglottica*, extending from the arytænoid to the epiglottis. The highly elastic fibro-cartilaginous *epiglottis*, rising upwards from the anterior and superior part of the thyroid, and capable of covering, during deglutition, the entrance of the glottis, is now almost always distinctly separate from the thyroid cartilage. In the cetacea, however, the epiglottis, as shown by Rapp and Henle, is still a mere process continuous with the thyroid cartilage, as in the lower vertebrata, and is in the dolphin and porpise, a thick firm cartilaginous mass, almost destitute of its usual elastic tissue.

As we ascend in the vertebrated classes, the distance between the arytænoid and the thyroid cartilages increases, and the connecting mucous fold, the *ligamentum aryepiglotticum*, on each side becomes, in proportion, more expanded over the entrance of the larynx, and now affords space for the development of the *cuneiform* cartilages, which are not found in inferior classes. The upper and lower pair of vocal ligaments, or *chordæ vocales*, and the intervening *ventricula morgagni*, are found in almost all mammiferous animals above the cetacea. The inferior vocal ligaments of mammalia are the analogues of those of reptiles, and principally form the rima of the glottis.

The three laryngeal muscles of birds and reptiles, are represented by three groups of muscles in mammalia. The *hyo-*, *crico-*, and *sterno-thyrioidei* muscles, lie in front, and the two last of these represent the *thyrio-tracheales* of birds; and the *glosso-epiglotticus* of mammalia is regarded by Henle as only a fasciculus detached from the *hyo-thyrioideus*, as the epiglottis here represents merely the anterior point of the thyroid cartilage of lower tribes. The *cricoarytænoidei postici*, ascending from the cricoid to the arytænoid cartilages in mammalia, (where we have already seen that the lateral

pieces of the thyroid cartilage of birds, have united to the cricoid,) dilate the entrance of the larynx. Now that the epiglottis is a distinct, detached and moveable part, the *ary-epiglotticus*, which in inferior classes acted only on the arytænoid cartilages, serves in mammalia, to depress the moveable epiglottis. The *crico-arytænoideus lateralis* has also shifted from the thyroid to the cricoid cartilage, and serves to compress the passage of the larynx, and a similar function is performed by the *thyrio-arytænoideus*, and the *arytænoideus transversus* and *obliquus*. And with this elastic, vibratile, and muscular apparatus, developed at the entrance of the respiratory organs of air-breathing vertebrata, they are enabled to regulate the quantity of air sent to or from the lungs, to protect these organs against the intrusion of foreign matter from the buccal or nasal cavities, and to vocalize the air transmitted through the trachea, so as to produce the various sounds of animals.

The development and metamorphosis of the branchial arteries, and the successive formation and closing of the branchial openings of the neck in the mammalia, present the same phenomena as in the inferior air-breathing vertebrated classes, and have often been observed and described in the human body, as well as in inferior quadrupeds, by Rathke, Baer, Ascherson, Burdach, Meckel, Müller, and other anatomists. The branchial arterial arches are successively formed from before backwards, and successively metamorphosed into the ascending cephalic and brachial arterial trunks, the descending aorta, and the pulmonary arteries, but no true branchiæ have yet been detected in this class, nor above the amphibia. Three or four branchial openings on each side of the neck, are commonly observed present at the same time, in mammalia, as in the lower classes; they appear and disappear in succession from before backwards, and the anterior openings on each side are generally much larger than the two posterior. In a human embryo three lines long, Rathke found the sides of the neck not yet perforated by the branchial openings; in the hog, they were open in an embryo only six lines long, also in an embryo of the horse only eight lines in length, and at an early period in the embryo of the sheep. Baer perceived three pairs of branchial openings, the anterior pair being much larger than the posterior, in a human embryo at the fifth week; and in

a dog's embryo of three weeks, he detected four branchial arteries co-existing on each side, with the minute rudiment of a posterior fifth pair. Four pairs of these openings were observed present at the same time, by Müller and by Burdach, in the human embryo about the fourth week; Rathke found three pairs of unequal openings in the human embryo, about the sixth week; and Ascherson has observed and described several abnormal cases, where remnants of these branchial openings were preserved through life, forming permanent congenital fistulæ in the human neck.

The same simple and uniform plan, followed by nature in the construction of all animal organs, is not less apparent in the development of the pulmonary organs of man and mammalia, than in that of their branchial apparatus. The lungs begin by a single simple follicle, as other glands, originating on the median plain, in a vascular blastema, on the fore part of the œsophagus, and soon extend downwards, bifurcate, and enlarge at their closed extremities, so as to constitute two simple pulmonary sacs, with a single membranous trachea, like that of fishes, or the lowest amphibia, or a lepidosiren. Peripheral septa begin to appear on the inner surface of their dilated part, the rudiments of future terminal cells. The trachea elongates, and irregular continuous spots of cartilage are perceived extending on its two sides, which rudiments of tracheal rings as yet neither meet in front nor behind, a condition preserved in the adult pulmonary organs of many amphibia, and the lowest reptiles. The peripheral septa extend inwards, to cancellate the pulmonary sacs, proceeding from their proximal towards their distal ends, as in reptiles. The lateral tracheal primitive cartilages, now extending their development upwards and downwards along the sides of that tube, become divided transversely, by absorption, into separate pieces, to form imperfect and incomplete tracheal rings. By the gradual approximation of these imperfect rings, on the median plain, before and behind, by their increased size and number, and by their enlargement and coalescence at the beginning of the air-tube, the annulated trachea and the laryngeal cartilages are distinguished and completed, as the uncancellated membranous tubular bronchi had been previously rendered distinct from the capaceous cancellated lungs. The tracheal

cartilages and fibrous structure are continued along the bronchi, and their ramifications, in the substance of the lungs. The laryngeal cartilages, by the successive formation and detachment of new elementary pieces, and the coalescence of others, pass through every inferior vertebrated form to the human type. The few simple laryngeal muscles and ligaments of amphibia and reptiles, become necessarily broken up into distinct parts, to form new muscles and ligaments, with different attachments and different functions. And thus, by a series of changes, complicated but uniform, of which no limit has existed in the past conditions or can be conceived in the future, the respiratory organs of animals have arrived at the type of the human pulmonary apparatus, by which his vital fluids are purified and replenished, his muscular system is furnished with its capability of action, his high temperature is preserved in every condition of the surrounding element, and his means of oral communication are established, which enable him to express his feelings and his wants, to communicate his accumulated knowledge, and to enjoy the most refined physical and intellectual pleasures of which his nature is susceptible.

CHAPTER FIFTH.

ORGANS OF SECRETION.

FIRST SECTION.

General Observations on the Secreting Organs.

The blood, replenished with fresh materials from the lacteals, and oxygenated by respiration, is fitted to be sent through the system for the nourishment of all the organs, and to afford the materials of all the secretions. But every living membrane in contact with a fluid, whether in the interior or on the surface of the body, exhales its own peculiar secretions; and in the lowest tribes of animals, all the requisite secretions are furnished from the fluids of the body, often without even the presence of a distinct sanguiferous system. The materials thus transuded through the porous texture of membranes, or the parietes of capillary vessels, are sometimes destined to form directly a part of the living system, sometimes to assist in the complicated process of the assimilation of foreign matter, and sometimes to form excretions to be discharged from the body. The secretions, however, are not mere transudations of the constituent materials of the fluids which afforded them, unchanged in composition and properties; they are generally altered, both in chemical and physical properties, during their transmission by nervous influence, or by the peculiar texture and form of the secreting membranes, or by the mode of distribution of the vessels. They are poured out alike by the external cutaneous surface of animals, and by its internal continuation the mucous lining of the digestive canal, or into the shut cavities of serous membranes, to lubricate the

surface of internal organs. The secerning membranes most generally present a tubular form, open at one end, and closed at the other, forming cells, or sacs, or follicles, or tubuli, or conglobate, or conglomerate glands, by which the largest secreting surface is accommodated in the smallest space, and the readiest transmission is afforded to the secreted matter; and the whole form and structure of these glands appear to become more complex, as the fluids they produce differ more from the constitution of the blood which affords them.

The alimentary canal traversing the interior of animals, itself lined with a secreting membrane, is the common passage for foreign matter through their body, and into which the most numerous streams of secreted fluids are incessantly pouring from all sides. Most of the glandular secretions poured into this canal, assist in the conversion of this material into chyle, to replenish the blood; and these chylopoietic glands, the most essential to life and growth, are the first formed in the animal body, and the most universal in their occurrence in the animal kingdom. Indeed, the whole processes of the nutrition and growth of every part of the organization, though not effected by distinct glands, may be considered as a series of secretions of their own materials, by all the different constituent tissues of the body. The first-formed secreting surface, and the most universal in animals, is the skin, and next, its internal continuation, the digestive canal; and nearly every distinct gland of the body, is developed from one of these two surfaces, which in most of the lower animals, are very similar to each other.

A mucous membrane, a mucous follicle, and a muciparous gland, are but different forms of the same surface, more or less extended, and more or less isolated, and adapted alike, under every form, for the distribution of capillary blood-vessels, and for affording their peculiar secretion. When these common secreting membranes have acquired a complicated and isolated form, so as to present, in small space, a large surface for the distribution of the capillaries, which afford the materials of the secretion, they constitute *glands*, which may thus be developed as isolated follicles, or the most ramified tubuli, from every mucous, cutaneous, or serous surface of the body. The adult forms of all glands in the lowest tribes of animals, and the earliest transient rudi-

mentary forms of the most complicated glands in the highest classes, are merely simple cœca prolonged from the surface on which they open. The transition from secreting lining or investing membranes, to secreting glands, is gradual and almost imperceptible, and the most complicated glands of the highest animals, as the liver and the pancreas, scarcely merit the name of glands in their first stages of development, or in the lowest tribes of animals.

As digestion is the most important function of organic life, and the digestive organs the most universal in animals, the largest, the most numerous, and the most important glands of the body, are developed from, and communicate with the interior of the alimentary canal. The duct of a gland is the gland itself, which may be a simple follicle, or a tubulus ramified so as to compose a conglomerate mass, like the liver; but this membranous duct, with its vessels and nerves, appear to be alone, though mysteriously, concerned in the production of the secretion. Not only are the liver, the pancreas, the salivary, and other chylopoietic glands, but ducts developed from the digestive canal, and minutely ramified towards their closed extremities, but even the urinary, the genital, and the pulmonary organs themselves, may be regarded as developments of the same kind. As the digestive canal is not only lined with a secreting membrane, continued through all its glands, but is also provided with a muscular tunic to move its contents; so we observe this fibrous contractile coat continued along the ducts of glands, to an indefinite extent, to expel the secretions from their interior.

In the first development of glands, the part from which they are to originate, becomes thickened, soft, and highly vascular, and constitutes a *blastema* or nidus through which the growing ducts are to ramify. The blastema somewhat indicates the form of the future gland, by its early division into corresponding lobes and lobules; and it becomes gradually absorbed, as the developing tubuli ramify through its substance. The glands which first make their appearance in the lowest animals, are those most important in the economy, those most constant in all the higher classes, and which attain the greatest magnitude and complication in quadrupeds and man; and there are many considerable temporary glands in the embryos of the highest animals,

which appear to attain no farther development than that of a simple deciduous blastema.

As a follicle implies merely a more elevated condition of a secreting surface, than a simple flat membrane, an aggregate follicular gland, merely a more advanced condition of a follicle, and a conglomerate glandular mass, merely a further development of a follicular gland; and as the same gland passes through all these forms, in the course of its development: so we find the highest of these conditions, the conglomerate form, to characterise the glands of the highest animals; and, in the lowest radiata, the cutaneous and the mucous surfaces afford all the requisite secretions, without even assuming the follicular form. All secreting glands, so far as their structure can be perceived, being thus merely membranous cœcal tubes, with highly vascular parietes, their peculiarities relate chiefly to trivial differences of form, size, situation, and products, throughout the animal kingdom, which admit of being considered either in zoological order, or by following separately, through all classes, the history of every individual gland.

SECOND SECTION.

Secreting Organs of the Cycloneurose or Radiated classes.

In the radiated classes of animals, which constitute the first stages of animal organization, the glandular form appears rarely necessary for affording the various secretions of their cutaneous or mucous surfaces; a copious mucous secretion is poured out from every part of their soft smooth cutaneous exterior, and from the mucous lining of their digestive cavities, without their appearing to require distinct cryptæ, or other forms of glands for its formation. The earliest developed, and the most constant gland in the animal kingdom, is the liver, the first formed and the most complicated in the highest animals, and the most important in the process of nutrition; and in the radiated, as well as in most of the articulated animals, this organ, so complicated and enormous in the vertebrata, generally consists of simple isolated follicles, more or less numerous, opening directly into the cavity of the stomach. The numerous intestinal cœca, or stomachs of *polygastric animalcules*, opening into

their alimentary canal, and the only distinct follicles perceptible in their body, may be considered as analogous to the *hepatic* cœca developed from the sides of the intestine, of long gastric cavity, of annelides. The hepatic follicles in most of the lower invertebrata, and in the first stages of their development in the highest vertebrated animals, admit the contents of the intestine into their interior, as well as in polygastrica. Were the secretions furnished by the interior lining of these follicles in the polygastrica, different in their characters towards the anterior and posterior ends of the digestive canal, the follicles nearest to the masticating organs, might be considered as *salivary*, and those nearest to the anus, as *urinary* glands, as in many articulata, but these differences and analogies are not established in this class. A larger single or double follicle, more various in form and colour, than the intestinal, and the small contractile follicle, seen in most polygastrica, have been imagined to be connected with the generative system, and the former to represent a *testicle*, and the latter a *vesicula seminalis*, but with as little evidence of such analogy. As the whole internal cavity of polygastrica, whether a canal as in the diacœlous and cyclocœlous forms, or a mere concavity as in the anenterous species, is most analogous to the gastric sac of higher animals; so are all its follicles most analogous to *hepatic* or biliary tubuli, forming the simple condition of the *liver* in these animals. Some polygastrica, as peridinium, synchæta, prorocentrum, illuminate the seas where they occur, but the source of their luminous secretion, is as little known as that of many higher animals. The flesh of *poriphera* forms a universal blastema for all the glands and other organs or higher animals, but in which none are yet developed; and if its constituent granules enjoy an independent existence, like the individuals of aggregate animalcules, they probably exhibit also in their interior, the hepatic follicles, or so-named stomachs of all other known polygastrica. Fine pellicles of mucus or epithelium are secreted by the sides of the internal canals of poriphera, and are constantly thrown out, along with the respiratory currents, from the numerous large vents of their surface.

From the fleshy surface of *lobularia*, and other *polypiphera*, thin mucous pellicles are periodically formed and detached,

like the periodical cuticular separations of most vertebrata. Some as *pennatula*, when excited, emit a bright luminosity, which is secreted by the individual polypi. These luminous secretions, so common in the radiated and the molluscous classes, appear to accompany the mucous secretions of the skin, or of the alimentary canal. Numerous zoophytes secrete from their surface large quantities of calcareous matter, mixed with a coagulating muco-gelatinous substance to form the solid extravascular skeleton of lithophytes, and others pour out upon their surface, or into their interior, a soft homogeneous coagulable matter, which soon hardens to constitute the flexible sheath or the axis of keratophytes. Many secrete colouring matters of various and vivid hues, sometimes along with the earthy matter of the skeleton, as the purple of *corallium*, *tubipora*, *melitœa*, and sometimes without it, as in the deep hues of *actiniæ*, *zoanthi*, *pennatulæ*.

The interior of the stomach of many zoophytes, as *actiniæ*, produces a copious secretion which appears to prove quickly fatal to, and quickly to dissolve their victims when seized and swallowed alive, and these parts of the stomach appear striated with thick opaque patches, like a blastema of future follicles. This condition of the secreting surface of the stomach, is more follicular in appearance in many *sertulariæ*, where it is reduced to minute aggregated coloured spots, like rudimentary biliary tubuli filled with their coloured secretion; and from the stomach of the polypi of *flustræ*, a distinct hollow follicle extends, forming an arrested development of a liver. We may regard, however, most of the glandular or secreting organs of these lowest classes, as still in their simplest condition of flat smooth secreting membranes, which have not yet developed even cryptæ or follicles to extend their surface, and to provide for the different kinds of products, and yet their secreting powers are often very considerable, and their products most varied. They present no distinct glandular structures for elaborating those very different materials from the food which they take in. Each species developes its gemmules always from determinate points of the body, and not indiscriminately from every part of the fleshy substance. We may consider, therefore, that even the ovarium, or the gland for secreting ova which is developed in higher classes of animals, presents itself here in a rudimentary state, as a

series of gemmiparous points of the common fleshy substance.

Most of the *acalepha* exhibit tubular prolongations, simple or ramified, extending from the periphery of their great gastric sac, by which the absorbent and secreting internal surface is increased, and the nutriment is distributed to a greater distance from the central cavity. These become more circumscribed tubular cœca, like biliary tubuli, in the stomach of *physalia*, *carybdea*, and other genera, and the analogies of these gastric cœca to the liver, have long been suggested by Eschscholtz, Edwards, and others. The marginal, cylindrical, opaque, granular bodies around the disk of many *medusæ*, have been regarded as the liver of these animals. Most of the species are known to secrete upon their surface a matter of a highly acrid, poisonous, and stinging quality, which appears to be furnished by every point of their surface, and which exerts peculiarly irritating effects on the human skin and other parts. I have experienced the violent inflammation and burning torture resulting from its application to the surface of the eye. Another defensive secretion of these animals, is the luminous material which appears to be connected with the mucous secretion of their surface, and to pervade nearly the whole class. The brilliant hues emitted by day, and the vivid light emitted in the dark, by *beroes* and other ciliograde forms, appear to be confined to the large vibratile cilia. The physograde species, secrete a gaseous fluid into their air-sac to assist in swimming, and some others as *physophora*, *porpita*, and *velella*, secrete a firm horny skeleton to support their soft parts. Some secrete a bright blood-red matter into their long slender tentacula, and the *velellæ* are covered with a soft substance of a deep violet-blue colour.

The small follicular cœca, sometimes ramified, which open into the digestive canal of *holothuriæ*, and into the wide gastric cavity of stellerida, are considered by Chiaje as constituting the liver of the *echinoderma*; but the hepatic tubuli of higher and lower allied classes have still more close analogies with the ordinary large ramified gastric cœca extending into the rays of *asterias*, and in other genera. If a difference of function existed in these gastric appendices, the smaller isolated follicles would rather represent a *pancreas* in these

animals, and the larger ramified cœca the *liver*. There are numerous distinct matters eliminated from the food by the vital processes of echinoderma, but very few developed glandular organs appropriated to their formation; the various colouring materials of the surface, of vivid hues, both in the naked and the testaceous forms; the numerous calcareous deposits of granules, spines, and shells; the copious solvent secretions of their digestive cavities, and the mucous secretions poured out on the surface of *holothuriæ*, and other naked species; the supposed calcifiant gland of the stellerida, which is a small vascular sac filled with a thick grumous secretion, consisting chiefly of minute calcareous crystals; and the numerous distinct sacs or tubuli, for the periodical development of ova. The internal branchiæ of *holothuriæ* have the form of long hollow ramified tubuli, and into their wide ducts, close to the cloaca, open several small isolated follicles, like a rudimentary kidney or renal tubuli; small isolated salivary follicles are observed also in some of the species, opening into the cavity of the mouth.

THIRD SECTION.

Secreting Organs of the Diploneurose or Articulated Classes.

The glandular organs of articulata are more distinct, more numerous, and more constant than in the radiated classes, but they still manifest the simplest follicular character, both in the ordinary chylopoietic, and in the newer and peculiar glands, and this simple condition of their chylopoietic glands accords with the nutritive character of the food in most of these parasitic or carnivorous tribes. The liver is rarely imperceptible in the *entozoa*, and has been long since shown by Rudolphi, Bojanus, and others; and salivary glands have also long been observed in the animals of this class, as in the trematode *diplozoon*, described by Nordmann, and in the *pentastoma*, by Cuvier. In most of the trematode and lowest forms of parenchymatous entozoa, as in many echinoderma and annelides, the liver consists of numerous ramified cœca prolonged from the sides of the digestive canal; and in the higher nematoid species, the biliary tubuli are restricted to small short follicles surrounding the long

gastric sac, or straight alimentary tube. The salivary glands consist of one or more simple undivided tubuli opening into the mouth, and even the testis and ovary have still the simplest glandular form of elongated tubuli.

The liver is not less obvious in the *rotiferous* animalcules, where it consists of isolated tubuli, varying much in their number and size, and opening directly into the wide gastric cavity. Two of these hepatic tubuli are seen in *brachionus urseolaris,* four in *megalotrocha alba,* seven in *diglena lacustris,* nine in *enteroplea hydatina,* some dozens surround the stomach in *rotifer vulgaris,* and in *philodina roseola* the entire length of the digestive cavity is closely enveloped with simple, short, straight, parallel biliary follicles, as in many of the higher annelides. These various tubuli are commonly dilated at their closed ends, as in most other glands; and the difference of form and place of insertion of these tubuli, would induce a belief of their having sometimes different functions, and representing both liver and pancreas, as in the *enteroplea hydatina,* where seven long narrow biliary tubuli open into the upper cardiac portion of the stomach, and at some distance below two very different short wide follicles, like the rudiment of a distinct pancreatic gland. The salivary glands are generally represented in the rotifera by two simple dilated follicles connected with the sides of the masticating apparatus. The male and female genital organs have also here a simple tubular structure, the internal branchiæ are in form of ramose tufts, the vesicula seminalis is a single median follicle, and a few of the species secrete upon their surface extravascular silicious laminæ, forming an enveloping sheath, like the polygastrica.

The high development of the chylopoietic glands of the *cirrhopods,* and the form and connexions of these organs, constitute further affinities between them and the molluscous classes, and accord with their imperfect means of selecting and obtaining the more nutritious kinds of aliment. The liver is of great size, and consists of innumerable small biliary follicles or cryptæ, arranged in clusters or acini, which form several lobes on each side of the stomach. These lobes surrounding the stomach open into different parts of its cavity by short wide biliary ducts, as in most mollusca. Two large conglomerate salivary glands pour their secretion

into the mouth near the masticating apparatus. The male and female genital glands have assumed a more complicated form, and the exterior secreting surface of the mantle pours out the calcareous matter of their complicated shell, and the dark coloured epidermis covering the peduncle of anatifæ.

Numerous small cœca, or biliary tubuli, are seen extending from the periphery of the digestive canal of many *annulida*, as the common earth-worm, which generally assume the saccular form of dilated follicles, as the gastric follicles of polygastrica, and are commonly filled with their yellowish-white coloured bilious secretion. These tubuli are very short, wide, and rudimentary along the sides of the stomach of the *leech*, excepting the last pair, near the pyloric valve, which have the narrow lengthened form of the hepatic tubuli of insects. In *halithea*, they arise by narrow openings from along the sides of the dorsal aspect of the stomach, they are much elongated, slightly ramified, and enlarge at their extremities into vesicles generally filled with digested or secreted matter. They are ramified also in planariæ and other annelides, as the prolongations of the stomach in many of the parenchymatous entozoa. From the biliary tubuli, such as they are, in the leech, extending along the entire length of the stomach, and ceasing to be developed at the pyloric valve, we more distinctly perceive the great extent of the alimentary canal which here corresponds to the gastric cavity of higher animals, and the relations of the hepatic tubuli to that cavity. The higher development and greater constancy of the salivary glands in annelides than in entozoa, corresponds with the higher condition of their masticatory and other organs, and the more mixed character of their food. Several salivary follicles open into the mouth of the *earth-worm*, as shown by Morren; I have observed two elongated salivary tubuli in the *arenicola*; and Brandt found them composed of clustered follicles in the *leech*. Besides the internal chylopoietic, and the male and female generative glands, we often find the naked surface of their body lubricated by a copious, thick, viscid, mucous secretion poured out from distinct glandular cutaneous orifices; and this is sometimes mixed with an acrid colouring matter, as we observe in the deep yellow secretion thrown out from the surface of the *arenicola*. Numerous distinct small round

muciparous follicles pour out a copious secretion generally near the orifice of the organs of generation, as seen in the earth-worm. Many annelides secrete from the surface of their skin calcareous or other matters to form exterior enveloping tubes for protection, and many minute marine species, when irritated, give out a brilliant fluctuating light of a bluish-white colour, extending in waves along the whole length of their body, and apparently subjected to the will of the animals. The testes and the ovaria, and even the pulmonary cavities, are still in form of simple glandular sacs, as in the earth-worm.

The liver of the *myriapods*, as in the *scolopendra* and the *iulus*, consists of long isolated biliary tubuli opening into the pyloric end of the elongated gastric cavity, as in insects, and the mouth is furnished with several pairs of long simple salivary follicles. In the *scolopendra gigantea*, there appear to be three pairs of elongated unequal salivary tubuli extending along the sides of the œsophagus, and opening into the mouth. The chilopoda have two poison-glands placed along the lower maxillæ, which convey their acrid secretion into the two unciform palpi placed at the base of the jaws. The genital glands are placed on different sexes, and are furnished with several accessory follicles; the pulmonary sacs or follicles of the annelides, have here become elongated tubuli, or ramified tracheæ; in the chilognatha, small glandular follicles open by minute orifices along the sides, near the haunches of the legs, which secrete an acid and strongly odorous fluid; and many myriapods emit a bright luminous appearance. Urinary tubuli are already observed in the *iulus* opening into the lower part of the alimentary canal at the beginning of the dilated colon or rectum, as in many insects.

The hepatic, salivary, pancreatic, and urinary glands, are distinctly developed in *insects*, and have generally the form of long isolated tubuli, often provided with small reservoirs, forming a urinary- and a gall-bladder, for the reception and accumulation of their respective secretions before being sent into the digestive canal. The salivary glands form one or more symmetrical pairs of simple tubuli, or clustres of follicles, opening by single ducts on each side of the mouth; and the dilated part of the œsophagus forming the crop, is generally surrounded with numerous minute muciparous

glandular follicles, which open into its interior. The long, capacious chylific stomach is also well provided with similar small, short, isolated follicles, the proper gastric glands, which open around its whole inner surface.

The *liver* of insects consists always of long biliary tubuli, varying much in their number, sometimes simple, sometimes with small follicles developing along their sides, sometimes isolated and free at their extremities, often anastomosing and continuous at their distal ends, and opening into one or more points near the pyloric extremity of the stomach. There are often two, or four, or six tubuli on each side of the stomach, and when thus few, they are very long and convoluted, and frequently united in pairs by the anastomosis of their distal ends, so that each tubulus returns to terminate in the part whence it originated. Sometimes there are several dozens of these tubuli, and when thus numerous, they are generally quite free, shorter, and separate at their closed ends, and open around more than one point of the stomach. These tubuli sometimes form a small sac, or gall-bladder, to collect their secretion before transmitting it to the stomach. By opening the stomach of the *bombyx*, and compressing the biliary tubuli, Malpighi in 1687, observed the yellowish coloured bile flow by a distinct aperture into the cavity of the stomach. The liver is least developed in carnivorous insects, as seen in *cicindela* (Fig. 118. C. *m. m.*) and in *cimex* (Fig. 118. D. *m. m.*), and most developed in the phytophagous species, as seen in *melolontha* (Fig. 118. A. *k. l. m.*); and the gall-bladder is sometimes double, as already seen in *pyrrhocoris* (Fig. 118. F. *f*).

The *pancreas* is less developed and less constant in insects than the liver, and commonly presents itself in the form of one or more simple follicles, opening into the pyloric portion of the chylific stomach, near to the entrance of the hepatic tubuli, as in *pyrrhocoris* (Fig. 118. F. *q.*), where, at least, six small pancreatic follicles are seen entering the stomach, close to the opening of the long hepatic tubuli. Numerous other relations of the chylopoietic glands of insects belong to the general account of their digestive organs already given.

The *urinary* organs, like most other glands of insects, consist of one or more elongated isolated follicles, or simple *tubuli uriniferi*, which open into the lower or cloacal portion

of the intestine, and sometimes develope a small vesicle, or urinary bladder, as in *ditiscus*, destined to receive their scanty secretion, which is found by analysis to contain urea, or a suburate of potash and ammonia, as the renal secretion of higher animals. Many coleopterous insects, especially the carnivorous species, possess glandular tubuli which pour a very acrid matter into the rectum, and in the hymenoptera there is frequently a poison-gland developed in the last abdominal segment, which sends its secretion through a perforated sting of great density and sharpness. The testes and the ovaries themselves, though more subdivided and complicated, present the same elongated follicular character of glandular tubuli. There are often numerous tubuli in the male, like vesiculæ seminales, connected with the vasa deferentia; and in the female we often observe, in the course of the oviduct, one or more glandular organs, apparently destined to secrete a fluid to envelope the ova, as they pass through the trunk of the united oviducts.

Many insects form a glutinous secretion from distinct glands, as from the two long tortuous labial glands of the silk-worm, which, after being thrown out from small apertures, hardens into fine silken filaments, destined sometimes to assist in their progressive motion, or to suspend their ova, or to entangle their prey, or to envelope and protect their own body while in the torpid pupa state. As in the lower classes of animals, numerous species of insects, when excited or alarmed, produce vivid flashes of light, which they are capable of prolonging for some time. There are often cutaneous follicles, which pour out on the surface, secretions possessing every variety of odour, as a means of protection when irritated; frequently the odorous glands contained within the segments, near the anus, can be protruded from the body and retracted at pleasure. Some insects have the odorous follicles placed near the head, or on the back, or along the articulations of the trunk and of the extremities. Glandular follicles on the lower part of the abdomen of the bees, secrete the wax in which they envelope their ova, and their honey is elaborated in the digestive organs, from the juices they have collected in sucking the flowers of plants.

The chylopoietic glands are but imperfectly developed in the carnivorous tribes of *arachnida*, where, however, we

observe several distinct *salivary* follicles in the trombidium, and other genera, and two in the scorpion; the *liver* consists generally of clusters of small follicles, which, in the scorpion, open into the stomach by five pairs of short hepatic ducts; and the *urinary* tubuli of the spiders form a small bladder, as in many insects, before sending their secretion into the cloacal part of the alimentary canal. The generative organs of both sexes still present the tubular character of elongated follicles, and poison-glands with poison-instruments are developed in these animals, sometimes at the anterior and sometimes at the posterior end of the body. In the scorpion, as in many insects, the last segment of the trunk is converted into a sharp, piercing poison-sting, which is here external, curved, solid at the point like the fang of a serpent, grooved at each side, and provided with two lateral canals continued from these grooves to the two poison-glands, which are situate above the broad dilated bulbous base of this exposed terminal sting. In the tarantulæ and spiders, as in the scolopendræ, among the myriapods, the poison-glands are situate at the sides of the mouth, and pour their secretions through the perforated, sharp, curved, maxillæ. There are four small follicular glands in the lower and back part of the abdomen in the spiders, which secrete the fine glutinous threads that compose the webs, and send their secretion through four ventral papillæ, in front of the anus, which are perforated with numerous very minute orifices, like the nipples of many mammalia. These filamentous glands can be suddenly compressed by the spiders, so as to throw out the threads to some distance when required.

Most of the numerous glands developed in insects and other air-breathing articulata, are incompatible with the aquatic life of the *crustacea*, which have fewer secreting organs than any other entomoid class. From the limited circulation of the blood in myriapods, insects and arachnida, their glands have generally a simple, isolated, elongated, tubular form, adapted to reach the fluids of the body; but in the aquatic forms of crustacea and annelides, where fewer glands are required, and where the sanguiferous system is more extensively distributed through the tissues for their nutrition, the secreting organs have a more subdivided, ramified, or conglomerate character, as the blood can be here

more easily sent to all their minutest subdivisions. In the simplest forms of the chylopoietic and intestinal glands in the lower articulata, the analogies of these minute secreting tubuli were determined chiefly by the parts of the alimentary canal into which they open, the *salivary* follicles opening into the mouth or œsophagus, the *hepatic*, *gastric*, and *pancreatic* into the long cavity of the stomach, and the *urinary* into the terminal or cloacal part of the intestine.

In the crustacea, however, not only are the different parts of the digestive canal more defined, but the character of the glands is also more distinct and obvious. From their aqueous habitat and the moist condition of their food, these animals, like fishes and cetacea, require no salivary glands, and rarely present a rudiment of these organs even in the highest decapods; the pancreatic glands, so nearly allied to them in function, follow nearly the same law of development, and only equivocal traces of them are perceptible in some of the entomostracous and higher species; and the rudimentary condition of these two important chylopoietic glands, corresponds also with the nutritious character of the food of these predaceous inhabitants of the waters. The chemical part of their digestive process depends, therefore, almost entirely on the liver, which is generally of great magnitude, minutely subdivided, and possessed of an immense secreting surface, as in the aquatic mollusca.

In the lower forms of amphipodous and isopodous crustacea, two or three pairs of isolated simple biliary tubuli opening into the elongated stomach, still compose the entire *liver*, as in insects; and in the simplest parasitic species, this organ is represented merely by a follicular development, or cellular covering, investing the parietes of the stomach, as in some of the annelides. The liver in the higher orders consists generally of a single duct on each side of the stomach, more or less subdivided and ramified, and with its ultimate tubuli disposed with perceptible symmetry, in lobules and lobes. In the most developed forms of decapods, both macrourous and brachyourous, the mass of small, short, straight, parallel tubuli biliferi arranged in lobules, and these in larger lobes, constitutes the largest organ of the body. These innumerable hepatic cœca are the terminal ramifications of two short wide ducts, which open into the narrow muscular

pyloric extremity of the capacious masticating stomach. They are connected together by their points of junction, by their common peritoneal covering, by a loose interposed cellular tissue, and by the minute ramifications of the hepatic arteries which afford the materials of their secretion. The branches of the two primary ducts determine the lobes, and their branches, the minuter lobules, and the terminal tubuli are commonly filled with their yellowish-brown coloured secretion. By removing a portion of the peritoneal investment, and agitating a small piece of the liver gently in water, the component tubuli, which are disposed with their shut ends around the periphery of the lobes, are easily separated from each other, and rendered obvious to the naked eye.

The soft green-coloured pulpy substance on each side of the œsophagus, composing the salivary glands in many of the decapods, more resembles a vascular blastema than ramified tubuli; and the pancreas of these highest crustacea, consists only of two or three elongated, simple, isolated tubuli, opening into the digestive canal, beyond the entrance of the hepatic ducts. The generative glands, the *ovaria* and *testes*, present a greater subdivision of their terminal, secreting, cœcal portion, and a greater distinction of this part from the efferent ducts, than in most of the inferior articulata. From the simple tubular structure thus presented by the various glands of the articulated classes, they not only exhibit permanent types of the primary transient stages of these organs in higher animals, but afford most instructive analyses of all the most complex conglomerate forms of secreting organs met with in the animal kingdom, and in the regularity of their forms and their bilateral symmetry, they surpass the glands of all other tribes of animals.

FOURTH SECTION.

Secreting Organs of the Cyclogangliated or Molluscous Classes.

The high development of the sanguiferous system in the molluscous classes, their mixed and inferior kind of food, and their imperfect means of locomotion, prehension, and

mastication, require a greater development and a more complex condition of the chylopoietic glands, than in the active and predaceous articulated tribes. Their slowness of motion or fixed condition, and their aqueous medium, are incompatible with many of the glands connected with the organs of relation, developed in the air-breathing animals of the former subkingdom, as the poison-glands of myriapods, insects and arachnida, the cutaneous follicles for odorous or acrid secretions to be poured on the surface of the skin, the filamentous glands for the webs of spiders, or the cocoons of insects. The molluscous animals are, therefore, provided with few secreting organs not immediately connected with nutrition or generation, and the great chylopoietic glands, the *hepatic* and *salivary*, are remarkable for their size, their constancy, and their conglomerate character, in this great subkingdom of aquatic animals. The liver is always contiguous to the stomach, and opens directly, for the most part by numerous wide orifices, into its cavity. The salivary glands are sometimes simple tubuli, sometimes conglobate clusters of short follicles, sometimes both these forms occur together, and they open generally by long ducts into the cavity of the mouth. The pancreas presents both the tubular and lobulated forms, opening, like the liver, into the cavity of the stomach, and the urinary organs terminate near the anus.

In the *tunicated* animals those glands only are developed, which are most essential to digestion and generation. The small short *tubuli biliferi*, sometimes as isolated follicles, and sometimes composing lobules, closely surround the greater portion of their stomach, and open into its cavity by numerous orifices; so that the liver in these lowest of the mollusca, presents nearly the divided and the concentrated forms, the two extremes of development, met with in the aquatic articulata, the lowest annelides and the highest crustacea. No salivary or pancreatic glands are perceptible here, or in the allied conchiferous mollusca. Besides their common genital glands, and the secretions of their mucous surfaces, pallial and intestinal, and the bright luminosity exhibited by many of the species, as salpa and pyrosoma, many of these animals attach to the exterior surface of their tunic, by means

of a glutinous secretion, particles of gravel, shells, and other substances, for concealment and protection.

The liver of the *conchifera*, as in the higher tunicata, consists of numerous small lobes, compactly united together, surrounding the pyloric portion of the stomach and part of the intestine, and opening freely by numerous short wide ducts into the capacious gastric cavity. The lobes consist of racemose groups of small dilated short biliary follicles, filled with their dark-coloured secretion, and opening into common anastomosing ducts, which penetrate the coats of the stomach by separate wide oblique orifices. In the situation of the pancreatic gland of higher mollusca, there is a single elongated and wide follicle opening into the stomach of many conchifera which secretes the firm cartilaginous material of the gastric dart, and salivary follicles are seen in some of the brachiopodous species, as in the lingula. A copious secretion of calcareous matter for the increase of the shell, is thrown out from the vascular exterior of the mantle, and a mucous secretion from its interior. In the abdomen, below the heart, is a considerable reticulate soft glandular organ and sac with two narrow orifices, near those of the oviducts, generally charged with calcareous particles and uric acid, and regarded by Swammerdam as the calcifient gland, by Blainville as a urinary apparatus, and by Bojanus as respiratory. Many genera, especially those provided with thin delicate shells, are fixed by a byssus, composed of strong dense filaments, secreted by a distinct gland at the base of the foot, and these filaments appear to be intimately united to the muscular or tendinous fibres reaching from the foot to the shell. The pearls formed by these animals are composed of spherical concentric layers of nacreous matter, secreted around foreign particles by the outer surface of the mantle, or in some by appropriate calcifient glands, and the same parts afford the various colouring matters which decorate the shells.

The glandular organs of the *gasteropods* are more numerous and distinct, and correspond with their more varied and active life. The hardness of their food now necessitates masticating apparatus, and these necessitate salivary glands, which keep pace with them in development. The salivary

glands, commonly one or two pairs, disposed along the sides of the œsophagus, and opening by long ducts into the mouth, consist sometimes of simple single elongated tubuli, as in *bullœa*, *aplysia*, and other genera, sometimes of racemose clusters of follicles, forming a compact lobulated organ, as in *arion*, *buccinum*, and many others, and sometimes these two forms occur together as in the *doris*. The liver, as in other mollusca, is of great size, consisting of numerous aggregated lobes, composed of small short tubuli filled with their biliary secretion, surrounding the greater part of the stomach and intestine, and opening by one or more oblique, wide orifices, into the pyloric end of the gastric cavity. The pancreas consists of a small single glandular cœcum, with thick follicular parietes, opening by a wide distinct orifice into the cavity of the stomach, close to the openings of the hepatic ducts, as in the *doris* and *aplysia*. The urinary glands are found to contain uric acid, as in conchifera, they consist generally of a conglomerate mass of small follicles, with a single efferent duct or ureter which opens externally near the anus, as in *arion*, *umbrella*, *pleurobranchus*, *doris*, *aplysia*, and other genera, and sometimes a small vesicle, or urinary bladder, is developed in the course of the ureter. These have also been regarded as calcifient glands.

Both in the naked and testaceous gasteropods, there are numerous muciparous follicles disposed on the surface of the body, to lubricate and protect the skin. In the testaceous pectini-branchiate tribes, there are often considerable muciparous glands disposed under the mantle to lubricate the interior of the pallial and respiratory cavities, and to protect them from the irritation of excrementitious and foreign matters. Many species present also at the bottom or near the margin of the pallial cavity, soft follicular glands destined to afford secretions of various and often lively colours, as the blue of the *janthinæ*, the yellow of the *bullæ*, and the purple of the *murices*. The *janthina* and the *glaucus* appear to derive their deep blue colouring matter, from feeding on the deep blue *velellæ*, which float with them near the surface of the sea. Chiaje found the purple secretion of the *murex tritonis* to be produced by the parietes of a glandular sac, situate at the bottom of the pallial cavity, and communicating with that cavity by a small foramen. The float of the *janthina*, by

which it suspends itelf and its spawned ova at the surface of the sea, is formed by a glutinous secretion of the mantle, enclosing globules of air.

The small swimming *pteropods*, both naked and testaceous, are, at least, provided with distinct chylopoietic glands. In the *clio* and the *pneumodermon*, single long salivary tubuli open into each side of the buccal cavity, and numerous hepatic lobes, composed of compact clusters of biliary follicles, and enveloping a large part of the intestine, open freely by short separate ducts into the cavity of the stomach. The liver of *hyalea* likewise consists of small aggregated biliary follicles, forming a compact lobulated mass investing the intestine, as in most inferior mollusca, before opening into the stomach. And the genital glands, both oviferous and seminiferous, have still the simplest follicular structure of isolated tubuli, or of a few racemose groups of small follicles, the ovary being, as usual, the more complex gland.

The secreting organs of the *cephalopods* approach nearer to the vertebrated type in their form, structure, and connections, than those of all the inferior invertebrata. Their diminished cutaneous mucous secretion is a further affinity with higher tribes, and is compensated for by the copious secretion of *muciparous follicles* in every part of the digestive apparatus, as well as by the higher development of all the normal chylopoietic glands. Two large pairs of lobed *salivary glands*, analogous to the *parotid* and *submaxillary*, consisting of aggregated lobules of small white dilated follicles filled with their salivary secretion, open by lengthened ducts into the back part of the buccal cavity, and correspond with the sharp and powerful cutting maxillæ, and the numerous recurved lingual teeth of these predaceous, though generally naked, mollusca. In the great size and the conglomerate character of the *liver*, and in its opening by a single lengthened duct near the pylorus, they indicate affinities to the fishes as well as to the lower mollusca. The short dilated parallel *tubuli biliferi*, filled with their brownish-yellow secretion, and directed with their shut ends towards the entire periphery of the organ, and of its component lobes, are easily seen with the naked eye, by removing carefully the thin, soft, investing peritoneum, and then floating a small piece of the liver in water. The *pancreas* here presents

itself sometimes in form of numerous isolated follicles, partially divided internally by peripheral septa, and opening separately into the hepatic ducts, as in *sepiola*, and sometimes in the more conglomerate form of distinct ramified tubuli, forming isolated lobes of racemose bundles of dilated follicles, opening by several common and slightly elongated ducts, into the trunks of the hepatic ducts, and also directly into the cavity of the third or spiral stomach, as in *loligopsis*. The pancreas, therefore, exhibits nearly the same variable character of development, and nearly the same connections as in fishes, and corresponds with the more advanced condition of the salivary glands in cephalopods; its connection with the biliary duct is that common in the vertebrated classes, and the cephalopodic type is repeated in the hepato-pancreatic duct of the dolphin and some other mammalia. The *spleen*, of which no trace has been detected in some of the lowest cyclostome fishes, appears also to be deficient in this, as in all the other invertebrated classes.

The *ink-gland*, developed as a means of protection in the naked cephalopods, and probably serving also as a urinary apparatus, consists of a highly vascular, simple cancellated sac placed on the ventral surface of the liver, and terminating by a single wide fibrous duct, in or near the anus, like the urinary and pigment-glands of gasteropods, and the anal or odour-glands of many vertebrata. The dark-coloured gelatinous *pigment* secreted by the parietes of the peripheral cells of this gland, and conveyed by the expired water through the syphon, to be diffused, for protection, through the surrounding element, corresponds in colour with the changeable cutaneous coloured spots, but no organic connection has been discovered between these distant parts. The ink-gland is deficient in the thick-shelled *nautilus*, and present in the thin-shelled *argonauta* as in the naked genera. The coloured secretion forming the changeable cutaneous spots, appears to be confined to small, isolated, highly expansible cells, situate on the vascular and sensitive surface of the cutis, and beneath the soft layer of epidermis. These small coloured cells continue to dilate and contract, and thus to vary the colour of the surface, even on small pieces of the skin detached from the body, and in the living state they appear to be regulated by the will of the animal,

like the vibratile cilia of many inferior tribes. The cellular follicles covering the great venous trunks on the ventral surface of the liver, and communicating freely with their interior, have been compared by some to urinary organs, and by others to the rudiments of a portal circulation. The genital glands here manifest the same elevated character of development as most of the other secreting organs; the testicle forms a large conglomerate mass composed of long, small, divergent, ramified *tubuli seminiferi*, with their closed extremities forming the periphery of the organ. The long vas deferens is convoluted like an epididymis, and is accompanied with a vesicula seminalis and a prostate gland. The ovary forms a large cluster of highly vascular secreting follicles, and the oviducts are furnished with distinct glands to secrete the enveloping materials of the ova, as in the plagiostome cartilaginous fishes.

The higher development of the secreting organs of the molluscous classes, is thus indicated by the greater number and greater sub-division of their component tubuli, and the more extended surface thence presented for the distribution of the blood-vessels which supply the materials of the secretions. It is seen in the concentration of all the constituent follicles and tubuli into single efferent ducts, and in the elongation of these ducts, by which the secreting glands are removed to a greater and more convenient distance from the parts whence they originate and which receive their secretions. The increased extent likewise of the vascular system in the molluscous classes, and the minute distribution of arterial capillaries through the glandular tissues, augment the products of the secerning organs. The efferent ducts are more distinct in form, structure, and function, from the follicular secerning portion of the glands; they terminate with more oblique and valviform orifices, and the analogies of form, connections, and function more closely approximate the glands of mollusca to the vertebrated type, than those of the articulated or radiated animals.

FIFTH SECTION.

Secreting Organs of the Spini-cerebrated or Vertebrated Classes.

As the general development of the glandular system of

animals keeps pace nearly with that of the entire organism, the highest condition of all the normal secreting organs is presented by the vertebrated sub-kingdom; and as the laws are most uniform by which the secreting surface of glands is gradually increased to the greatest extent, and the secreting organ itself is confined to the smallest space, it is in this division of the animal kingdom that most glands have permanently assumed their most compact and most conglomerate forms. The vertebrata, like the entomoid articulata, being chiefly active air-breathing animals, with a high development of the *organs of relation*, they exhibit a corresponding high condition of all the secreting organs connected with the functions of *animal life*. They have therefore the most numerous and the most varied forms of glands, and the most diversified in function connected especially with their cutaneous covering, their tegumentary apparatus, their organs of the senses and of locomotion, besides the highest condition of all those secreting organs more immediately connected with individual nutrition and with generation.

The *fishes*, like the uterine embryos of higher tribes, are, from their aquatic habitat, still nearly in the condition of the molluscous classes, with relation to their secreting organs, and they exhibit chiefly those most essential to nutrition and generation. From the moist condition of their food, and their want of proper masticating teeth, from the shortness and width of their œsophagus, and their swallowing their food almost without division, from the aqueous constitution of saliva, and the constant streams of water flowing through their mouth for respiration, fishes require no salivary glands, and they are more appropriately provided with numerous and large buccal muciparous follicles, which lubricate and protect the capacious cavity of the mouth and pharynx. Similar mucous glands are developed along the parietes of the œsophagus, and they abundantly perforate the mucous lining of the stomach and intestine, as indeed in all the vertebrated classes, and on most mucous surfaces throughout the animal kingdom. As the aquatic respiration of the mollusca is not effected through the mouth, this function does not interfere with the great development of their salivary glands; but in fishes where the dense aqueous element is respired solely by the mouth, this function is incompatible with the ordinary

salivation of food, and the development of salivary glands. The imperfect aeration of their blood by means of this aquatic respiration, is probably also connected with the preponderant development of their liver, that great emunctory, supplemental to the lungs and branchiæ in decarbonizing the blood.

The liver is large in fishes, as in mollusca, of a soft texture, divided into numerous lobes, its tubuli are filled with a very light coloured oily secretion, and there is generally a distinct gall-bladder superadded to the ordinary biliferous cœca composing the entire liver of invertebrata. The gall bladder is sometimes wanting as in ammocetes, or a mere dilatation of the hepatic duct as in petromyzon. The great size of the gall-bladder and its constancy in this class, accord with the carnivorous habits, and the consequent irregularity in the supply of food, in most of the species, as seen also in the reptiles and the predaceous tribes of other classes. As the capillary blood-vessels furnish incessantly the materials of the secretion, and the tubuli of the liver as constantly form bile, the interruptions to the demand for that fluid, by the irregular feeding of almost all carnivorous animals, necessitate the development of a reservoir in the course of the efferent duct, to prevent the bile from irritating the empty intestine in time of fasting, and to afford a sufficient supply for their excessive meals. In most herbivorous animals, with a constant abundance of food, and an unceasing process of digestion, no reservoir or gall-bladder is wanted, but rather a constant and copious supply of bile direct from the tubuli and ducts of the liver; and thus the presence or absence of this appendix, and its extent of development, are related more or less obviously to the food and habits of animals.

The liver of fishes is often disposed on the left side, or on the median plain, or towards the right side of the abdomen, being suspended by broad ligaments from the tendinous diaphragm, and is generally deeply lobated, extending backwards, in front of the alimentary canal, as far as the pelvis, and often partially enveloping the intestine as in the mollusca, but without the central excavation often seen in the liver of invertebrata. There are commonly one or more long hepatic ducts, which unite with a long cystic duct from the large gall-bladder, to form a short and wide common ductus choledochus which opens into the commencement of the duodenum, immediately

beyond the pyloric valve, and close to the opening of the pancreatic duct. Besides the hepatic artery, common to the invertebrated classes, in which it alone furnishes the materials of the bile as well as the nourishment of the liver, this organ in fishes is supplied with several portal veins, derived chiefly from the chyloposetic viscera, which ramify with the hepatic artery along the pinnated tubuli of the liver, affording the bile from the mixed blood of their capillaries. The portal veins are less extensively ramified through the liver in fishes and the lower vertebrata than in the higher warm-blooded classes, as in the earlier conditions of the human embryo. There are frequently hepato-cystic ducts in fishes which convey the bile directly into the fundus of the gall-bladder, as well as the usual hepatic ducts leading to the cystic; and sometimes as in the orthagoriscus, the bile is still poured directly into the cavity of the stomach, as in most of the invertebrated classes.

From the aqueous nature of the pancreatic secretion, that gland, like the salivary, is little required in fishes, and is there found, as in the mollusca, chiefly in the simplest follicular form, occurring as a single pyloric follicle in the ammodites, and arriving at the most conglomerate form in the highest cartilaginous fishes. In some fishes where the free pancreatic tubuli are still wanting, as the cyprinus, esox, muræna and ophisurus, their place is supplied by a simple cellated or follicular structure of the internal lining of the duodenum. The pancreatic follicles of this class open into the duodenum, close to the biliary duct, beyond the pyloric valve, by a most variable number of orifices, according to the degree of development or concentration of the organ. The follicles, when simple, are commonly cylindrical, aggregated into groups, and open into the duodenum by several apertures sometimes nearly as wide as the intestine itself; but in the most conglomerate form of this organ, in the plagiostome fishes, the common duct of all the minute tubuli composing the lobules of the pancreas, terminates by a single and narrow orifice. The spleen first makes its appearance in the class of fishes; it is sometimes wanting as in the lamprey, the myxene, and the gastrobranchus, generally it is small and single, but in some cartilaginous species it is divided into detached lobes, as in some of the cetacea; it is appended to the left side of the stomach, and is highly vascular and largely supplied with lymphatics.

Notwithstanding the scaly covering of fishes, their exterior surface is generally lubricated by a copious viscid mucous secretion poured out on different parts of the body, from long, ramified, subcutaneous, muciparous glands. These simple glands are especially distinct and numerous on the head and sides of cartilaginous fishes, where they form long tortuous tubes filled with their white mucous secretion. In many of the osseous fishes they form a continuous tube extending along each side of the body to the end of the nose, and sending down branches along the operculum and the lower jaw. These muciparous vessels, like other secerning tubuli, secrete at all points of their course, and pour out their secretion on the surface from distance to distance as they proceed below the skin, and they are often seen following the course of the longitudinal lateral line on both sides of the body.

Besides the ordinary secretions of the pulmonary, the urinary, and the generative apparatus, many fishes both of fresh water and of the sea, and both osseous and cartilaginous, are provided with complicated electrical organs, presenting an immense secreting surface in small space, and by which they are able to communicate violent shocks to animals which touch or approach them. In the gymnotus these organs consist of an upper larger and a lower smaller pair, and occupy the inferior part of the whole caudal region of the body. They are divided by numerous closely approximated transverse membranous folds, and these horizontal compartments are further subdivided by innumerable thin vertical laminæ like the plates of a galvanic pile, with a mucous secretion interposed between the layers, and filling all the cells thus formed, and they are largely supplied with nerves, as are all the electrical organs of fishes. The two distinct electrical organs disposed along each side of the body, are separated from each other by firm tendinous membranes and by muscles, and they extend tapering to the end of the tail. The membranous septa are highly vascular to furnish their abundant secretion, and they are supplied with symmetrical pairs of spinal nerves derived from the whole course of the spinal chord. In the torpedo the electrical organs occupy a large space on each side of the head; they are composed of numerous small vertical compartments, each of which is regularly subdivided by a series of horizontal parallel septa or thin membranous laminæ,

enclosing the mucous secretion, and they are supplied with large branches from the fifth and eighth pairs of nerves. The frequent excitement of the electrical organs appears to exhaust rapidly the influence of the ganglionic nerves of digestion and secretion, and to arrest these processes. The highly vascular secreting organ, connected with the parietes of the lungs of fishes, and which appears to produce the gaseous contents of the air sac when destitute of ductus pneumaticus, has been considered analogous to the thymus gland of higher vertebrated classes, but it is here a permanent and essential part of the pulmonary sac.

From the aquatic habits and the imperfect masticating powers of the *amphibious animals*, their salivary glands are nearly as little required and as little developed, as in fishes or in cetacea, but their buccal cavity, like the naked surface of their skin, is abundantly provided with muciparous follicles, and the whole course of their digestive canal. The liver, as in fishes, is proportionately large and always provided with a large gall-bladder, and it is partially divided into two lobes, as in most reptiles. In the pipa there is a third intermediate lobe, and they are more free, as in the chelonia. The liver commences in the tadpole by a small pit or crypta on the side of the intestine, like the concavity left in the adult liver of many mollusca; from this a few small simple short follicles gradually extend; these increase in number, elongate, and divide to constitute at length the entire mass of the adult organ. The pancreas is always conglomerate, as in the plagiostome fishes, and opens into the duodenum beside the biliary duct. The highly vascular spleen, is single as in reptiles, of an elongated form like the stomach, and is attached by cellular tissue and vessels along the left side of that organ, as in higher vertebrata. The muciparous glands, so largely developed and extensively ramified immediately beneath the skin of fishes, assume a more divided form on the naked skin of amphibia, where they pour out their viscid and sometimes acrid secretion, by open pores dispersed over all parts of the surface. The excretory orifices of these cutaneous follicles are large and obvious over the back of the land salamander, and their acrid product in the toad is alkaline, not acid like most other excretions. The glandular follicles which secrete this bitter, oily, and poisonous fluid on the back of the toad, are chiefly disposed on the dorsal

part of the broad short neck, and appear to serve as a means of defense. No unequivocal thymus gland appears to be developed in the amphibia or in the fishes, and it is only a deciduous organ of the fœtus in higher vertebrata.

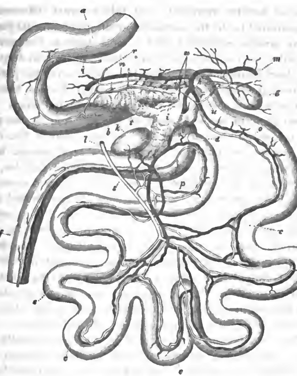
The impervious scaly covering of terrestrial air-breathing *reptiles*, is less compatible with the high development of cutaneous muciparous glands, than the soft and often naked skins of aquatic vertebrata, and this external deficiency is compensated for by the increased secretions of internal glands; nearly similar conditions exist in most birds and mammalia. The sublingual salivary glands are always distinct in serpents, and also the superior and inferior labial glands, and the parotids or foliated temporal glands in the noxious species, transmit their poisonous secretions through the perforated fangs. The poison gland of serpents occupies the situation of the parotid, below and behind the eye, on each side of the head, and consists of numerous symmetrical compressed lobes, each composed of minute diverging branched follicles, and the common duct of all the lobes passes forward along the side of the upper jaw to the base of the perforated fang, where it enlarges to form a wide reservoir for the secretion, and is surrounded with muscular fibres to compress it when required, and force the poison into the tooth. The upper and lower labial or maxillary glands consist of vertical, parallel, simple, contiguous lobes opening into the mouth by separate orifices. The salivary and muciparous glands are also distinct in the saurian, and especially in the chelonian reptiles where the submaxillaries are most developed.

The liver of reptiles is large, little divided externally into lobes, composed of minutely pinnated follicles or acini, provided with a gall-bladder, and an extensive portal circulation, and there are commonly hepatic ducts passing directly from the liver to the duodenum, besides the duct from the gall-bladder. This organ varies its external form with the general form of the animals, being remarkably elongated in the ophidian, broad in the chelonian, and intermediate in the saurian reptiles. The hepatic ducts of the ophidia alternate with the separate ducts of the pancreatic lobes, in their points of entrance into the duodenum, near the pyloric valve. The pancreas presents a more concentrated form in sauria and chelonia than in ophidia, and the spleen is also relatively small in serpents where it is closely united to the

pancreas, sometimes divided into separate lobes, and sometimes it is quite imperceptible.

The relative position of the ducts of the chylopoietic glands, as viewed from behind in the *emys europæa*, is seen in the annexed figure from Bojanus (Fig. 145) where *a. b.*

Fig. 145.



represent the elongated stomach, *c. d.* the small intestine, *e. f.* the cœcum and colon, *g.* the gall-bladder opening by two ducts into the duodenum *h.* one of which ducts receives the hepatic and may be considered as its continuation. The pancreas (*i.*) intimately connected with the stomach, the duodenum and the colon, opens by three separate ducts (*u. u.*) into the duodenum, and has the spleen (*k.*) compactly united to its inferior lobe. The gastro-epiploic (*q.*) the cœliac (*r.*), and the mesenteric (*l.*) arteries ramify as indicated, the upper lobe of the pancreas receiving the pancreatic artery from the cœliac, and the inferior lobe receiving branches from

the mesenteric artery, along with the spleen. The veins (*o. p.*) returning from the alimentary canal, the spleen, and the pancreas, unite below the liver to form the *vena portarum* (*h.*) which ramifies through the right (*m.*) and left (*n.*) lobes of that organ.

As the alimentary canal passes straight through the body in the embryos of vertebrata, the great chylopoietic glands, the liver and the pancreas, are developed from its anterior part, on the median plain, like the lungs from the œsophagus. In the embryo of the lizard, the liver appears at first as a short, hollow, bifid follicle continued from the intestine, and numerous tubuli bud out from the whole surface of its thick vascular parietes, which extend, ramify, and compose the entire lobules and lobes. The thymus gland, which first makes its appearance in the reptiles, is there a permanent organ, as it is also in some of the lower mammalia, as the cetacea and the rodentia. Some predaceous saurians, as the aligators, possess distinct anal glands, like many carnivorous quadrupeds, which secrete a strongly odorous substance, having the odour of musk, and the same structure appears to belong to some chelonian reptiles, and to the rattle-snakes and many other serpents, both noxious and innoxious. Besides these anal musk-glands, most of the crocodilian reptiles present two simple follicular glands under the lower jaw, which pour out on the surface of the skin a thick fluid with a similar musky odour. In some lizards, these odorous glands open by distinct external apertures on each side of the anus, and in most of the saurian reptiles there are numerous external inguinal pores for the discharge of a similar strongly odorous secretion at the breeding season. The cutaneous follicles of the Indian gecko secrete a fluid which is said to have the same acrid and poisonous properties as that of the toad. The glandula lachrymalis and Harderi are already distinct in the orbit of reptiles, and even in serpents where the skin passes transparent and continuous over the front of the eye-ball; and the urinary and genital glands have here attained a high development.

The liver is already perceptible in the embryo of *birds*, as of the fowl, on the third day of incubation, and appears as a simple bifid hollow projection from the anterior median aspect of the straight alimentary canal. These two follicles or primitive lobes extend, enlarge, draw out the digestive tube to in-

crease their internal cavity, develope from their vascular and thickened periphery innumerable rudimentary tubuli, the proximal cervix becomes contracted and extended to form the duct, and from the parietes of the duct a small diverticulum protrudes to constitute the future gall-bladder. In the substance of the vascular enveloping blastema, the minute plumose ramifications of the tubuli, of which the adult organ is chiefly composed, are observed compactly aggregated together, and apparently as yet without internal cavities, and they are destitute of the terminal vesicular enlargements seen at the closed ends of the pancreatic and salivary tubuli. The liver in birds is still relatively large, variable in form and in the number of its external divisions, with the left lobe generally smaller than the right, and a distinct middle lobulus Spigelii. There is still a separate hepatic duct which passes into the duodenum above the entrance of the cystic, one or more hepato-cystic ducts end in the fundus of the gall-bladder, and the separate hepatic and cystic ducts open into the intestine at a considerable distance below the pyloric orifice of the stomach. The gall-bladder is often wanting in this class.

The pancreas still opens as in reptiles by several ducts, which penetrate the duodenum between the openings of the hepatic and cystic ducts. The small spleen of birds is sometimes divided into separate lobes, as in some fishes, serpents, and cetaceous mammalia. The thymus gland is a transient organ in birds, as it is in most mammalia, and it makes its appearance late in the progress of development in these classes, as it appears late in ascending through the classes of the animal kingdom. Two small thyroid glands are recognizable in many birds near the inferior larynx; and most birds, especially the aquatic species, present over the dorsum of the coccyx, two contiguous pyriform oil glands, composed of straight parallel tubuli; which open on the skin by several papillar orifices, and afford the unctuous secretion with which the feathers are dressed to render the plumage impermeable to water. In most birds the rudiment of Cowper's glands is observed as a single or bifid follicle, *bursa Fabricii*, opening into the median dorsal part of the cloaca, between and behind the openings of the two ureters.

All the ordinary secretions of birds, from the high tempe-

rature of their body and their great muscular activity, are formed, expended, and reproduced with comparative rapidity, the mucous secretions of their buccal, nasal, and intestinal cavities, the serous transudations into shut cavities, as the abdomen and the pericardium, and especially the oily synovial secretions into the capsules of their ever-active joints. The fluids of the eye, the ear, the lachrymal, the Harderian, and the nasal glands, the œsophageal, ingluvial, and gastric or proventricular glands, and the secretions of the oviducts, are all rapidly expended and reproduced in this most active and hot-blooded of all the vertebrated classes. This condition of the secreted fluids of birds is not dependant on a more highly developed or complicated structure of their glands, which are still comparatively simple, but rather on the rapid transmission of highly arterialized and heated blood through their texture, and the high development of the nervous system on which the secretions so immediately depend.

The secreting organs have mostly arrived at their greatest complexness in the *mammiferous* tribes, as indicated by the number and minuteness of their ultimate tubuli, their separation from the surface from which they originate by the elongation and concentration of their ducts, by the formation of reservoirs to retain and accumulate the secretions, and by the size and vascularity of the entire glandular masses. The plan of development, however, in every gland, appears to be the same as in lower classes, commencing by simple follicular protrusions from the formative surface, which acquire thickened vascular parietes, forming a blastema, for the further production of cœca and ramified tubuli, to compose the lobules and lobes of the gland, and thus to increase the extent of surface over which the capillary blood vessels are spread to afford the materials of the secretion. The salivary glands commence from the mucous membrane of the mouth as simple follicles, these bud out from their periphery further follicles and ramified tubuli, which extend through the soft vascular and lobulated blastema, the closed ends of the tubuli forming small vesicular enlargements, and the blastema gradually disappearing as its space becomes occupied with the developing secerning tubes. The blastema early assumes a lobulated exterior form, corresponding with the future lobed

structure of the gland, and the minute terminal vesicles of the ultimate tubuli appear clustered in racemose groups forming small lobules or acini. The parotid, submaxillary and sublingual salivary glands attain the greatest development in the herbivorous quadrupeds where there is longest mastication and the coarsest food; they are smaller in the carnivorous tribes where there is less mastication and richer food, and they are deficient in the cetacea where the moist food is mostly swallowed entire.

The liver begins in man and mammalia, as in other vertebrata, by a simple follicular protrusion, like the embryo condition of the pancreas, from the anterior median surface of the yet short straight intestine. Its parietes thicken to constitute a soft vascular blastema, and new follicles and ramified tubuli are prolonged through the substance of this deciduous formative nidus. The primitive follicle becomes narrow and elongated to form a duct, and thus to separate the gland from the surface of the intestine, the duct develops a small filiform diverticulum, which widens and elongates to form a gall-bladder and cystic duct. And in the adult state of this most complicated of all glands, in this highest class of animals, where the tubuli have arrived at their maximum of subdivision, they are still perceptible, larger than capillary blood-vessels, constituting in groups the acini and nearly the entire mass of this large organ, and when successfully inflated with air, their shut ends have appeared to Krause to form minute dilated vesicles, like the lungs and most other glands. The arrangement of the minute cœcal tubes, forming the lobules or acini by their grouping, is perceptible on the outer surface of the liver through the transparent peritoneal covering, or on cutting open the larger trunks of the vena portæ or venæ hepaticæ and carefully inspecting their inner transparent parietes. This minute lobulated appearance, seen on all the peripheral parts of the liver, was shown by Malpighi to be produced by the innumerable small ramifications of the proper secreting ducts, which he found to constitute the essential part and the mass of all secreting glands, and which here generally assume the symmetrical forms of foliaceous or pinnated expansions of small white cylindrical secerning tubuli, in all parts of the organ. Into these minute terminal follicles, and their connecting continuous secerning trunks, the bile is transuded

from the mixed blood conveyed by the united capillaries of the vena portæ and hepatic artery, the diameter of the ultimate divisions of the tubuli, as in other glands, much exceeding that of the capillary blood vessels which afford them the materials of the secretion. But although the more trivial circumstances of the size and mode of grouping of the tubuli, and the outward form and bulk of the entire mass, vary in the different tribes of mammalia, and the mode of distribution of the blood vessels through the organ, we still find this largest and most complicated gland to consist, in the highest as in the lowest animals, merely of a membranous duct, or prolongation developed from the parietes of the alimentary canal, destined to augment the secerning surface, for the more extensive distribution of capillaries, and to form a more convenient reservoir of this stimulating and solvent secretion. From the chemical composition of the bile, the liver appears to perform a function somewhat similar to that of the lungs, and its development in animals is generally in the inverse ratio to that of their respiratory organs.

The secretion of the liver, which in the lowest animals is poured directly into the stomach, to reach the food early, and to act upon it during the whole of its short passage through the body, now always enters the alimentary canal at some distance beyond the stomach, the food being here acted upon by numerous other secretions, and having a long course to pass through after leaving the stomach. As all parts of the liver, like the parts of the lungs or other secreting organs, have the same function to perform, they are shaped or fissured into lobes, according to the forms of the surrounding parts or other convenience in the different tribes, being least lobed in the inactive abdomen of the lowest aquatic mammalia, the cetacea, more divided in the herbivorous quadrupeds, and most fissured in the active trunks of many carnivora and rodentia, where its primitive péripheral lobules sometimes remain distinct through life. But even the external forms and peripheral divisions of glands, manifest the same uniformity of plan, as other the most trivial parts of the economy, as the position of the intestinal turns in the abdomen, the cerebral convolutions in the cranium, or the direction of the hairs on the several parts of the skin.

The gall-bladder is most generally deficient in the her-

bivorous tribes, and in some its place is supplied by a mere dilatation of the hepatic duct, as in the horse and elephant, and the same is seen in the dolphin; it is most constant and most developed in the carnivora; it is sometimes double or even triple as abnormal varieties; and its fundus still often receives several hepato-cystic ducts as in lower classes. In the dolphin and grampus, where, as in most cetacea, there is no gall-bladder, nor pyloric valve to mark the termination of the gastric cavities, the united duct from the liver and pancreas opens directly into the muscular duodenal dilatation, commonly termed the fifth stomach, and the dilated reservoir supplying the place of gall-bladder in the dolphin, as in the elephant, is an enlargement of the common trunk of the hepato-pancreatic duct, receiving, like the duct of a cephalopod, the secretions both of the liver and pancreas. The vena portæ forms a sinus in the dolphin before dividing in the liver, and in the diving seals and otters the trunks of the hepatic veins are surrounded with a contractile muscular tunic, which is immediately invested with an exterior plexiform layer of the small returning anastomosing branches of the intra-lobular hepatic veins, to allow of the safe contraction of these muscular hepatic trunks. In the echidna and ornithorhyncus the gall-bladder is present, along with a dilatation of the common biliary duct, seen also in several marsupialia, before piercing the duodenum; the pancreatic and common choledochal ducts continue separate, and have distant terminations, in the echidna, but these two early unite in the ornithorhyncus, to form a common hepato-pancreatic duct.

The liver is proportionately large in the human embryo, as in the lower vertebrata and the molluscous animals in their adult condition. The follicular structure of the embryo-liver was already observed by Malpighi in the chick, before the end of the first week of incubation, and before the end of the first month, the liver in the human embryo has attained nearly half the weight of the entire body, and is lobulated like the kidney of a bear, and extended backwards to near the pelvis. The gall-bladder early makes its appearance as a developing cylindrical tubulus, and gradually becomes more elongated, conical, hollow, muciparous, rugous internally, and at length biliferous; the liver becomes less

gelatinous and pellucid, more firm, opaque, red and vascular, and the biliary and pancreatic ducts, originally separate, coalesce by the drawing out of the intervening portion of intestine during development.

The pancreas opens by a single duct, sometimes into the ductus choledochus, and sometimes separately into the duodenum, although the division of this organ into two lobes is perceptible in most of the mammalia; these lobes consist of smaller aggregated lobules or clusters of ramified tubular cœca, ending in vesicular enlargements like the salivary follicles; and the organ commences its development, like the liver, from a small median cœcal protrusion from the fore part of the intestine, which sends out follicles and ramified filiform tubuli through the thickened soft vascular blastema. The spleen, in many of the cetacea, is divided, as in many lower vertebrata, into several detached, small, round, portions, connected only by sanguiferous and lymphatic vessels; it is single and large in the ruminantia, of a regular elongated form, and attached along the side of the paunch.

The mucous surfaces of mammalia are every where provided with muciparous follicles, presenting the simplest forms of glands, and the alimentary canal has its simple follicular glands of Lieberkuhn and of Peyer; more complicated forms of these muciparous organs exist in the labial, buccal, palatine, molar, and amygdaloid glands, the caruncula lachrymalis, and several connected with the urinary and genital apparatus. The serous membranes have also their secreting surfaces and bursæ, to preserve the mobility of the viscera and joints. The mammary, urinary, and genital glands present numerous modifications in this class; and the tegumentary organs are every where provided with their simple sebaceous follicles, and their more complicated sudoriferous and oil glands, as the eyes are furnished with their simple Meibomian and complicated lachrymal glands, and the external meatus of the ears with their ceruminous glands.

From the different habits and external circumstances of the animals of this most varied class, many of the secreting organs are so modified as to appear special developments limited to tribes or to individuals. The most odoriferous parts of the skin of mammalia are sometimes developed into distinct follicles or more complicated glands, as in the inter-

digital spaces in most ruminantia where we observe between the hoofs a tubular and slightly ramified glandular cavity, which affords an oily secretion of a strong and peculiar odour, to lubricate and protect the hard extravascular hoofs, and by which the carnivorous quadrupeds are better enabled to trace the footsteps of their prey. Some of these ruminating quadrupeds also exhibit simple cutaneous odorous inguinal glands, opening on the surface near the mammæ, and developed in like manner from odoriferous parts of the skin. The strongly aromatic musk of the musk-deer is secreted by two glandular sacs, opening near the prepuce of that animal. The spur of the ornithorhyncus was shown by Meckel and Rudolphi to transmit through its tubular canal the poisonous secretion of a large gland placed in each thigh. In rodent quadrupeds there are numerous glandular follicles, situate near the anus or near the prepuce, which secrete strongly odorous, sebaceous, or oily fluids. Two plicated glandular sacs are found on each side of the genitals of the male and female beaver, which pour out, near the organ of excitement, the well known fatty and resinous secretion, the castoreum of medicine; and the most conglomerate form of the gastric glands is seen at the cardiac orifice of the stomach in this animal and in the wombat, which aids the digestion of their coarse vegetable aliment, and points out a closer analogy between this part and the glandular stomach, or ventriculus succenturiatus of birds. In many rodentia the shut extremity of the long cœcum-coli is closely covered with small simple glandular cryptæ, which open into its cavity, and similar rudimentary glands, in clusters of simple follicles, occur in various parts of their alimentary canal. Anal glands, secreting odorous substances, are also met with in several of the marsupialia and pachyderma, but they are most developed in the carnivorous quadrupeds, where their secretion is remarkable for the intensity of its odour in the civets, badgers, hyænas, and some other genera. In the elephant, similar odorous glands are seen in the region of the temples, opening externally on each side by a small round orifice, between the eye and the ear.

But notwithstanding the infinite diversity of form, structure, and position of these secreting tubular membranes, forming *glands* throughout the animal kingdom, and the

various modes in which the blood-vessels and the nervous filaments are distributed on their surface, no general or determinate relation has been discovered between these structural conditions and the peculiar properties of the secretions they produce. In their most complex conglomerate forms, the biliferous, uriniferous, seminiferous, and other secerning tubuli, like so many vascular systems, convey their fluid contents, eliminated from the blood, always in one direction, from the sanguiferous system, as the chyliferous and lymphatic systems convey theirs to the mass of the blood. And although the mode of action of these various emunctories of the circulation, in producing chemical changes in the fluids they transmit through their parietes, be, like the transmissive powers of nervous filaments, yet unexplained, the most perfect regularity of system and unity of plan are not less apparent in the development of *secreting organs* throughout the classes of the animal kingdom and the embryos of individuals, than in the nervous or other important systems of the animal economy.

CHAPTER SIXTH.

LYMPHATIC SYSTEM.

In the lowest tribes of animals, all the assimilative functions are performed by the same simple digestive cavity which receives the raw material from without; but as we ascend in the scale of organization, the functions become more complicated in their result, and special organs are appropriated to the several portions of the complex process of nutrition. In the first condition of the vascular system in the radiated classes of animals, the arteries are scarcely distinguishable from the veins in structure or in function, and to this simple plexus of ramified tubes, in which the blood often takes a retrograde course, are confided the functions of chylification, sanguification, circulation, and even absorption. And throughout the highest of the invertebrated classes, the absorption of nutriment from the intestine, and the absorption of the decayed materials from

all parts of the body, appear still to be confided to the ordinary sanguiferous vessels. In the complex systems of the vertebrata, however, a distinct chyliferous apparatus is appropriated to the absorption of the nutritious part of the food, and to its conversion into chyle or almost into blood, and in the same elevated tribes of animals a distinct vascular system, the *lymphatic* or absorbent, is allotted to receive the decayed materials from every point of the body, and to convey them to the blood, to be discharged with the excretions.

The lymphatics appear to be porous or absorbent at all points of their surface, as the tubuli of glands are secerning throughout their course, and probably both these sets of permeable tubes are equally closed at their commencements. By the introduction of these absorbents into all the tissues of the body, they are enabled to grow by intus-susception, and to retain all their proportions while they increase in bulk. From their function they have been termed absorbents, and lymphatics from the limpid fluid they convey. Though differing in function from the lacteals, as the lacteals from the veins, or the liver from the kidney, they have nearly the same relation to the venous or sanguiferous system, and enter it at the same place, through the medium of the thoracic ducts, which are canals common to the chyliferous and lymphatic apparatus. While the lacteals convey only chyle to the blood, and originate solely from the alimentary tube, the lymphatic absorbents convey the dissolved tissues of every living organ, and originate from or traverse every point of the body; and although these two systems first appear simultaneously in the class of fishes, the plexiform convolutions of their vessels, forming their so-named ganglia or conglobate glands, appear earlier in the lymphatic than the chyliferous system. The limpid contents of these vessels are sometimes yellowish, reddish from the presence of blood globules, or whitish in colour, they contain albumen and fibrin and easily coagulate, and they convey globules, like chyle, blood, or milk.

The lymphatics abound in the tissues of all the vertebrated classes, following the course chiefly of the larger and deep-seated arteries and veins, and occurring over all the subcutaneous parts, so that they appear to confer the

property of rapid absorption on all the mucous and serous membranes, and on all the other tissues of the body, by their quickly conveying the transuded matters to the circulating blood, and they become exquisitely sensitive in the inflamed state. They commonly exhibit two distinct coats, an outer dilatable fibrous tunic, and an inner smooth, less elastic, serous coat which forms internal crescentic folds or semilunar valves. The valves are commonly in pairs, directed towards the heart, less numerous than in the lacteals, and apparently deficient in some of the viscera, as the lungs, the liver, and the uterus. The anastomoses of the lymphatics are much more frequent than those of the veins, which occur much oftener than in the arteries; they probably commence by closed orifices, like the tubuli of glands. The lymphatics form numerous so-named conglobate glands or ganglions, consisting of plexiform sub-divisions convoluted into small tubercles, with afferent and efferent lymphatics leading to and from these pseudo-glands, like the nervous filaments in sympathelic ganglia; and muscular pulsating cavities are sometimes developed on the lymphatics, like the pulsating sacs on the sanguiferous system of many invertebrata.

In the class of *fishes*, where the existence and the extensive distribution of the lymphatics have been long known, they have been observed in almost every form of osseous and cartilaginous species, excepting in the lowest cyclostome fishes, as the myxine and the lampreys, but they have not been detected in the invertebrated tribes, where their function, like that of the lacteals, appears to be performed by the sanguiferous capillaries. The lymphatics of fishes were early examined and described by Monro, Hewson, Fohmann, Meckel, and others, who injected them with fluids, inflated them with air, and pointed out their yet simple structure, apparently consisting of a single very thin tunic, their want of internal valves, excepting at their entrance into veins where there are generally valves, their distribution throughout the textures and organs of the body, especially over the superficial parts, and their supposed free communications with the venous system. Instead of the distinct compact conglobate glands presented by this system in the warm-blooded classes, we here observe occasional groups of crowded tortuous anastomosing lymphatics, presenting a kind of analysis of

the higher forms of these so-named lymphatic glands or lymphatic ganglia. The few small lenticular bodies like lymphatic ganglia observed in the neck of the roach have been considered by some as mesenteric glands, and were regarded by Meckel as the first rudiment of the thymus gland, which he considered, as well as the spleen, as merely a lymphatic gland. Monro observed the deficiency of the ordinary lymphatic glands in fishes, and considered the long subcutaneous muciparous follicles as lymphatic vessels opening by large orifices on the surface of their skin, and thence supposed that all lymphatics must have similar open orifices.

Besides extending as a continuous network over all the deep-seated and superficial parts of fishes, they already cover by their numerous plexuses, as shown by Fohmann, the entire surface of the larger veins, especially when they are distended with injected matter, and from the extensibility of their soft thin coats, they generally appear very wide and sacculated, and present numerous transverse constrictions of their parietes, at irregular distances, as if from the commencing development of valves. The direct communications of the lymphatics with many branches of veins pointed out by Fohmann, have been more recently ascribed by Panizza and others, entirely to rupture of the injected vessels and to transudation, not only in fishes but in all higher classes. The large sacs and receptacles commonly observed on the injected lymphatics of fishes, are, for the most part, produced by the pressure of the injected matter on the thin distensible sides of these vessels. There are commonly two great lateral plexuses of lymphatics on the trunk of fishes, passing forwards to terminate with the anterior ventral plexus, in the thoracic ducts behind the heart; and the lymphatics of the head and dorsal parts of the body enter the ducts anterior to this point, after forming considerable plexuses near their entrance into the anterior cava or into the jugular veins. The lymphatics from the posterior parts of the body unite with the lacteals from the intestine, to form two great trunks before ending in the receptaculum, which forms the commencement of the two anastomosing plexiform wide thoracic ducts. They form a compact layer of plexiform vessels around most of the organs of the abdomen, as around the spleen, the large pancreatic

tubuli, the liver and gall-bladder, the testes and ovaria, and even the minute laminæ of the gills where their larger branches follow the course of the branchial arteries along the concavities of the arches.

The lymphatic vessels have been shown by the numerous careful injections of Panizza, Muller, and others, to be no less extensively distributed through every part of the body in the naked batrachian animals or *amphibia*, than in the fishes, and they are maintained by Panizza to be here, and in all higher classes, a distinct, isolated system of vessels, from their origin to their termination, by great trunks, in the venous system. He has represented, in his splendid plates, taken from his own preparations, the crowded distribution of these plexiform and beaded vessels, over all the subcutaneous parts of the body, and forming compact layers around the interior viscera, especially on the spleen, in frogs and salamanders among the amphibia, as well as in serpents, lizards, crocodiles, and tortoises, among the true reptiles; he considers the skin as altogether different in properties from mucous membranes, and that the batrachia are incapable of respiring through their soft and naked skin. Between the skin and the subjacent muscles of the higher amphibia there are large lymph spaces which appear to communicate freely with the lymphatic vessels, they are readily filled by inflation of the lymphatic hearts, and they usually contain a considerable quantity of lymph which escapes on cutting the skin. The great receptacle or thoracic duct of the frog, forms a wide continuous sac extending along the whole dorsal region of the cavity of the trunk, above the abdominal viscera; the large receptacle of the salamander, in extending forwards, divides and reunites, and again bifurcates before entering the two subclavian veins.

Muller at Berlin and Panizza at Pavia discovered, about the same time, two symmetrical pairs of pulsating muscular cavities, on the large brachial and crural lymphatics, in the regions of the neck and pelvis in the naked amphibia, and similar pulsating sacs have also been detected on the lymphatics of some reptiles and birds. The pulsations of these lymphatic sacs are not synchronous with those of the heart, nor even with each other; and they continue after the heart has been dissected from the body, or the body cut to

pieces. In the frog the anterior pair are situate below the posterior edge of the scapula, and above the broad transverse processes of the third cervical vertebra, the posterior pair on each side of the free end of the long coccygeal bone, quite superficially near the sides of the anus; they are seen pulsating, about sixty times in a minute, through the skin of the entire animal without dissection, and they propel the lymph collected from the anterior and posterior parts of the body and extremities, into the neighbouring venous trunks. They contain only the usual colourless lymph, and by distending them with air the lymphatics of the extremities become inflated, and also the lymph spaces beneath the skin. The anterior pair of these lymphatic hearts propel their contents, on each side, into a branch of the jugular vein, which becomes distended by each contraction of the sac, and the posterior pair send their lymph on each side into a branch of the ischiadic vein. The posterior pair of these pulsating sacs are the more constant in their development, and have been observed, where the anterior were imperceptible, in salamanders, serpents, and saurian reptiles. They are provided with simple valvular folds at their orifices in the python, where they send their lymph into branches of the renal veins.

The structure and distribution of the lymphatic system of *reptiles* have been illustrated by the researches of Bojanus, Panizza, and other anatomists, especially in the chelonia, where they present great facilities for their investigation, from their great size, their extensive distribution, and the still imperfect development of their valves. The imperfect development of the valves in the lymphatics of all the reptiles, still allows injections to pass from the larger trunks of these vessels towards their branches and capillaries, and hence the convenience and the facility of illustrating their distribution through the textures and organs, by preparations from this class, especially from the vegetable eating chelonian reptiles, where they are largest and most extensively developed. They are always wide and dilatable vessels, and they present a knotted or beaded appearance, most conspicuous when filled, injected, or inflated, from the constrictions caused internally by the valves, and the dilatations of the elastic parietes of the vessels between the valves. Suc-

cessfully injected preparations of the lymphatics in the chelonian reptiles, show almost every organ of their body, to be permeated and covered over with a compact layer of these wide absorbent vessels. They are remarkably crowded on the surface and in the interior of the spleen in the chelonia, as in the amphibia; and Tiedemann supposed that all the chyliferous vessels of the mesentery in these cold-blooded classes, pass through the spleen before entering the thoracic ducts. The thoracic ducts form generally two wide irregular anastomosing canals, most dilated at the receptaculum, which convey the lymph and chyle to the veins of the neck.

The lymphatic glands or ganglia are not yet developed in the reptiles, and their place is supplied by the tortuous windings and subdivisions of parts of the vessels themselves, as in the lower cold-blooded vertebrata, which indeed is but a less concentrated or a more unravelled and simple condition of the compact lymphatic ganglia of higher animals. Panizza detected a small pulsating muscular sac on the lymphatics proceeding from the posterior part of the trunk on each side, in the coluber flavescens, like those discovered in the amphibia, and they are found in many of the saurians; they are nearly an inch long in the python. He has not been able, by all his injections, to discover a single direct entrance of a lymphatic vessel, or of a lacteal into a vein, even in the lymphatic and mesenteric glands of the higher vertebrata, and he ascribes the communications pointed out by other observers, to the rupture of vessels, and the extravasation of the injected matters, especially in the glands, where the minute lymphatic capillaries twine round and interlace with the veins. The more recent researches of Muller and other anatomists have also tended to establish the isolated condition of the absorbents, in all the vertebrated classes, throughout their entire course to the great normal trunks by which they terminate in the venous system; and Duvernoy supposes that such free communications as have been presumed between absorbents and veins, at least between the lacteals and the branches of the vena portæ, would tend to diminish and deteriorate the chyle destined to nourish and replenish the blood, by expending its principal constituents in the formation of bile.

The spleen of the tortoise, by successful injection, is made

to appear like a mass of absorbents, where the finer internal vessels accompany the divisions of the veins through its texture, and the larger exterior lymphatics form by their confluence, a considerably superficial sinus. They abound on the mucous and serous membranes and throughout the adipose substance of this animal, they present a regular arborescent appearance on the testicle, and are comparatively rare on the liver, the gall-bladder and the œsophagus. The distinct compact external intestinal layer of absorbents, probably belongs to the lymphatic rather than to the chyliferous system. In the crocodile and the green lizard, Panizza found the lymphatics particularly abundant and forming distinct layers around the cloaca and the terminal portion of the intestine, the heart of the crocodile appeared enveloped in a plexiform layer of these vessels, but he could not inject those of the liver, the testicle, or the pericardium. In the turtle, the crural plexuses derived from the lymphatics of the posterior extremities, together with the renal, the rectal, the cloacal, and the sacral plexuses, unite with the lymphatics of the peritoneum, the adipose substance of the abdominal parietes, and part of the lungs, and the great chyliferous trunks, to form the wide reticulate commencement of the anastomosing thoracic ducts, which envelope and almost conceal the abdominal aorta, as they advance forwards, collecting the lymphatics from all surrounding parts, to terminate in their respective subclavian veins. In the alligator, four great chylo-lymphatic trunks unite and separate several times, before they collect on each side to constitute two lateral thoracic fasciculi, which receive the neighbouring lymphatics as they advance, and terminate in the two subclavians. In the lizard the thoracic duct advances single through part of its course, but divides anteriorly into the usual two branches, before ending in the veins; in serpents they continue separate from the receptaculum.

In the class of *birds* the lymphatics are less wide and sacculated than in the chelonia, their parietes are more firm; they are smaller and more numerous than in reptiles, and the valves formed by crescentic folds of their serous lining are more developed. Their course is now generally more direct, and their plexuses in the neck are occasionally developed into distinct small lenticular conglobate glands, though

they are not yet developed on the chyliferous vessels of the mesentery. They are here seen, as in other classes, clustered in reticulate plexuses around the great blood vessels of the extremities and of the trunk. The lymphatics from the lower extremities and the posterior parts of the trunk, enter a large plexus or receptacle at the origin of the cœliac artery, along with the lacteals from the lower portion of the intestine. Those from the head and anterior parts of the body enter the two great trunks of the thoracic ducts, to pour their contents along with the chyle into the angle between the subclavian and jugular veins. As many as six lymphatic glands have been detected on each side of the neck, in some of the larger predaceous birds. Injected matters can still occasionally be forced to pass through the lymphatic vessels, from trunk to branches against the direction of the valves, and Lauth sometimes found the injections extravasated between the two coats of these vessels in birds. In the goose, he observed the lymphatics extending along the sides of the toes and over the interdigital membrane, forming a plexus on the tarsus and lower part of the leg, collected behind the knee into a single femoral trunk, which enters through the crural arch into the pelvis; here they form a plexus, on each side, enveloping the renal veins, and send their principal trunks into the renal or the sacral veins. The chyliferous plexuses chiefly envelop the mesenteric, cœliac, and aortic trunks, and, after receiving several lymphatics from the abdominal and pelvic viscera and the posterior parts of the trunk, they collect to form the commencement of the thoracic ducts. The lymphatics from the lungs and œsophagus, and from the wings, enter the thoracic ducts before their termination in the jugular veins, and the same ducts receive also the lymphatic trunks from the sides of the head and neck, excepting a branch from the right cervical trunk which opens separately and directly into the right jugular vein, and the left thoracic duct sometimes sends branches to open separately into the left subclavian.

The fibrous and serous coats of the lymphatics, and their general external cellular investment, are more distinct, especially in the larger trunks, in the *mammalia*, than in lower classes; their symmetrical pairs of opposed semilunar valves are more numerous, more complete, and more effective in

guiding the course of the contained lymph, and in preventing the flow of injected fluids against their natural direction. The compact aggregate masses of convoluted lymphatic capillaries, forming the conglobate glands, so rarely met with in lower vertebrata, are now general, distinct, large, and numerous in the course of these vessels. They abound especially in the inguinal and axillary regions, on the sides of the neck, and along the course of all the great veins. The lymphatic ganglia of mammalia are common in the general cavities, and around the great viscera of the pelvis, abdomen, and thorax, and even in the interior of organs, as along the divisions of the bronchi in the substance of the lungs. They are commonly more concentrated, fewer, and larger in the inferior quadrupeds than in man; and from their deficiency in the cranial cavity, where lymphatic vessels abound, their office appears to be incompatible with the delicate functions of the brain. They are often tinged by peculiar contents of their vessels or by the colours of the surrounding parts, especially after death, as in the vicinity of the liver, the spleen, and the bronchi, and they often acquire a cellular appearance internally, as in the cetacea, from dilatations of their minute convoluted tubes, or of their connecting cellular tissue. Though they do not occur within the skull, the lymphatic glands are common on the exterior parts of the head, as behind the ears, beneath the lower jaw, and on the inside of the parotids.

The lymphatic vessels not only form integrant parts of all the organs and tissues of the body, but by injection many of them appear to be almost entirely composed of these vessels. Though smaller in mammalia than in lower classes, they are more numerous and more extensively distributed, they are much larger than the capillary blood-vessels which spread on their parietes, they are wider than the terminal tubuli of most glands, and their minutest branches are perceptible by the naked eye. Their subcutaneous layer now forms a more compact and continuous stratum over all the superficial parts of the body, as they appear also over all the mucous and serous membranes of the interior, forming an inextricable network as little provided with, and as little requiring villous commencements or orifices as the sanguiferous capillaries they accompany, and in which the limpid,

colourless, coagulable, imbibed fluids are moved forwards to the blood by the vis absorbendi, the pressure and movements of all surrounding parts, and by the direction of the valves now crowded in their interior. The valves, as in portions of the venous system, are sometimes deficient in their interior, as in the lungs, the liver, and the uterus, and notwithstanding their distinct fibrous coat, considered by Meckel and others to be muscular, and the obvious rithmic pulsations of their muscular sacs in many of the lower vertebrata, no pulsatory movements or spontaneous contractions have yet been discovered in any portion of the lymphatic system of man or mammalia.

The general distribution or the typical form of this vast system in the mammiferous animals, is seen in that of the human body where, as usual, they have been detected and most investigated, after their discovery in inferior tribes. Collecting the lymph from the superficial parts of the feet, these vessels form an outer cutaneous group, ascending behind the external ankle and the back part of the leg to the small popliteal glands, and an inner cutaneous group, ascending along the inner side of the knee and forepart of the thigh, to the superficial inguinal glands. From the deeper parts of the feet the lymphatics collect around the arterial trunks, as the cutaneous do with the great veins, and ascending with the peroneal, the anterior and the posterior tibial arteries, they traverse the popliteal glands, and continue their course with the femoral artery to the smaller and deeper seated glands around that vessel in the inguinal region. Throughout their whole course these lymphatic trunks are reinforced by numerous branches from all the surrounding parts, and numerous lymphatics from the exterior of the pelvis, the abdomen, and the genital organs, likewise meet to traverse the inguinal glands. The efferent lymphatics from both sets of inguinal glands enter the pelvis, through the crural arch, with the great blood-vessels, and proceed along the external iliac artery to the large and numerous lumbar glands, and all the arterial trunks issuing from the pelvis are accompanied by numerous lymphatics from the neighbouring parts, proceeding inwards to the same destination, and thence to the thoracic duct.

The absorbents from the urinary bladder, the prostate, the

deeper parts of the penis, the clitoris, and the vesiculæ seminales, like those of the uterus, enter the glands along the internal iliac artery, the ovarian have a higher termination; the large rectal lymphatics proceed to the sacral and lumbar glands, and those of the testes accompany the spermatic arteries to enter the latter glands, and the renal and suprarenal lymphatics have the same termination. The splinic absorbents accompany the blood-vessels, form a series of small glands; receive the lymphatics of the pancreas, and part of those from the stomach, and proceed with the lacteals towards the general receptaculum; those from the superficial and the interior parts of the liver, proceed partly through the diaphragm and mediasterium to the right lymphatic duct, and partly backwards to the great left thoracic or chylo-lymphatic duct, both sets forming numerous glands in their course. Both the superficial and the deep-seated absorbents of the lungs meet in the bronchial glands, and the efferent ducts of these small glands ascend to terminate respectively in the right and left thoracic ducts; the lymphatics of the heart accompanying the coronary vessels to the base of that organ, and forming glands in their course, likewise ascend by the sides of the trachea to open into both thoracic ducts, and those of the thyroid gland have a similar double termination. The lymphatic glands or ganglia thus extensively developed on all the absorbent trunks in man and mammalia, appear to exert an influence in animalizing the serous residue of nutrition which they convey, as the chyliferous glands exert on the chyle they convey to nourish the blood.

As in other parts, the absorbents from the head and neck follow chiefly the course of the sanguiferous vessels, the superficial generally accompanying veins, and the deeper-seated the arterial trunks, and forming numerous small glands in every convenient part of their course. The lymphatics which descend with the temporal artery on each side, traverse the zygomatic and parotid lymphatic glands, and continue to the numerous glands of the neck lying near the junction of the external jugular with the subclavian vein; those which descend posteriorly with the occipital artery, traverse the post-auricular glands, and terminate with the former in the cluster of cervical glands. The numerous exterior ab-

sorbents accompanying the facial vein traverse the submaxillary lymphatic glands and those seen over the buccinator muscle; the deeper branches of the face pass likewise through the glands at the angle of the jaw, in their course downwards to the mass of lymphatic ganglia at the base of the neck. And the efferent vessels from these glands which receive most of the absorbents from the head and neck, unite on each side to form single trunks which enter the right and left thoracic ducts, or sometimes directly the subclavian or the jugular veins. The anterior termination of the great chylo-lymphatic duct is still irregular and divided, like its posterior commencement; and although this common centre of the chyliferous and lymphatic systems is now single in most of its course, it exhibits traces of its double and plexiform condition in most lower vertebrata, by the divisions and anastomoses which it still seldom fails to present in different parts of its course in mammalia and in man.

The course and distribution of the lymphatics of the arms, correspond much with those of the posterior extremities, forming a superficial series mostly accompanying the cutaneous veins, and a deep seated group following the course of the great arteries. The principal cutaneous absorbents of the anterior extremity ascend on the palmar side of the hand, wrist, and fore-arm to the bend of the elbow, where they form one or more glands, seldom seen in lower mammalia, and continue their course on the inside of the arm, enlarging by the accession of branches from all surrounding parts, to the cluster of glands in the axilla. The smaller superficial group proceeds along the dorsal part of the hand and arm, and along the course of the cephalic vein to the subclavian glands. The deeper-seated lymphatic trunks accompany the radial, ulnar, inter-osseous, and brachial arteries, communicating with the cutaneous absorbents, and terminating in the group of axillary glands, which receives also the lymphatics from the anterior and posterior parietes of the thorax. The efferent trunks from these large axillary glands follow the course of the subclavian artery, on each side, and open with other lymphatic trunks into the right and left thoracic ducts, or sometimes directly into the subclavian veins.

The axillary and inguinal lymphatic glands are more subdivided and detached in man than in most lower mam-

malia, where they are seldom observed in the ulnar or the popliteal regions. These glands are also more compactly united together, and into fewer groups, on the head and neck, and in most parts of the body, in the lower quadrupeds than in man, as shown by Gurlt in several of the domestic species; this accords with their smaller number of lymphatic absorbents, and of convenient places for their assuming the glandular form. In like manner, where the intestines and mesentery are long, and afford extended space for the distribution of chyliferous vessels, as in herbivora, quadrumana, and man, the mesenteric glands are numerous, small, detached, and spread separately over a large surface; and where the alimentary canal and mesentery are shorter, as in carnivora, these glands are more approximated, aggregated, and often compactly united into the so-named pancreas Asselii. And thus the lymphatic system, though late in its commencement in the animal kingdom, and still mysterious in its function, has advanced by regular and progressive stages to a condition more uniform in character than the chyliferous, and higher in development, by the possession of a rudimentary heart, and has approached the sanguiferous system in the elaboration of its parts, and in its vast distribution through the organs and tissues of the body.

CHAPTER SEVENTH.

EXCRETING ORGANS.

The residue of the nutrition of all the organs and tissues, and the decayed materials of animal structure, imbibed by the parietes of lymphatics from all points of the body, and conveyed by them to the blood, prepare that fluid to afford the materials of various excretions, to be removed from the system by distinct internal organs or by the general surface of the skin. But animals without lymphatics, and even without blood-vessels, alike possess the means of dissolving and separating from their fabric the old materials which for

a limited time have formed part of their system, and this endowment is essential to their development and growth, and constitutes the principal phenomenon of their nutrition and of their life. The effete materials of their nutrition are pouring incessantly in a gaseous or in a fluid state, from the exterior cutaneous surface of the body, or from the internal mucous surface of the alimentary canal and its appendages, in all classes of animals, from the polygastrica to the mammalia, however inappreciable those products may often appear. Repair and decay, nutrition and excretion, may alike be regarded as secerning processes, where dissolved materials permeate the parietes of capillary tubes; and where those secreted materials do not appear subservient to some useful purpose in the maintenance of the individual or of the species, they are regarded as *excretions*, and the parts which form them *excreting organs*, whether they communicate with the internal mucous lining of the alimentary cavity or the exterior cutaneous covering of the body.

All excreting organs, by extracting their products from capillary blood-vessels spread on their surface, have a secerning function, whether performed by simple membranes, follicles, tubuli, or other forms of glands, and a precise limit can scarcely be assigned to the excrementitious character of glands and secretions. The luminous, the electrical, and the stinging materials evolved by many of the inferior tribes, are but little connected with the processes of nutrition or of generation, as are also the numerous poisonous fluids, inky secretions, and odorous materials formed by animals for self-defence, but unequivocally less are the gaseous and aqueous materials evolved by the respiratory organs, the fluids perspired by the skin, and the heterogeneous product of the kidneys. As in all other glands connected with organic life, the most important and the most developed forms of excreting glands originate from the interior of the alimentary canal, and are safely protected in the deeper cavities of the body, while the more simple and minute forms of these organs, and the most numerous, are developed from the skin and spread over the whole exterior of the body.

FIRST SECTION.

Internal Organs of Excretion.

The most complicated and the most distinct of all emunctory apparatus developed in animals, are the *urinary organs*, which early appear in the animal scale and in the embryo, and exert the most immediate and extensive influence over the condition of the vital fluids, and the entire economy. Developed in the vertebrated tribes, from the cloacal end of the alimentary canal, like the lungs from the buccal extremity, the urinary, like the pulmonary organs, excrete largely the aqueous constituents with other materials of the blood, and both these complex secerning organs remove their heterogeneous products by the terminal openings of the digestive tube. As carbonic acid is the most characteristic ingredient of the pulmonary excretion, so are uric acid, or urea, and lithic acid, both abounding with nitrogen, the chief urinary products; and as the structure of no gland is yet indicative of its function, the lowest and most ambiguous forms of the urinary organs are determined rather by their general analogies of form and connections, and the chemical nature of their products, than by any peculiarity of internal structure. . The urinary organs thus corresponding in function, and complimentary, to the respiratory, commonly however exhibit less tendency to ramification and vesicular dilatation in their ultimate tubuli, than the lungs and most other complex glands.

The means of respiration possessed by the simplest forms of animals, whether internal or external, may serve likewise as general emunctories for the urinary and other excretions, without the necessity of special organs for each of these products. As all parts of the body in the radiated classes of animals, the cutaneous, mucous, and serous surfaces, are constantly bathed by ciliary currents of the surrounding liquid element, the excretions may be removed directly from every point of the system without distinct organs for their elimination. The tubular, ramified, internal respiratory organs of *holothuria* (Fig. 114. *h.*), developed like renal glands from the cloacal end of the alimentary canal, and extending like the kidneys of vertebrata along the interior of the

trunk, have obvious affinities, both to urinary and branchial organs, and may perform the function of both these great emunctories. Distinct isolated follicles, (Fig. 114. *i.*), however, more resembling simple urinary tubuli, are already perceptible in this animal, developed from the cloacal end of these large organs, and to which the urinary function may be confined. The calciferous gland of the asterias may have a similar function.

Although numerous salivary, mucous, and biliary follicles pour their secretions, partly excrementitious, into the alimentary canal in the helminthoid animals, no distinct formation of uric or lithic acid has hitherto indicated a urinary function in any of these simple glands. Among the entomoid articulata, many insects and arachnida exhibit, besides the ordinary biliary tubes opening into the higher chylific portion of the alimentary canal, distinct small secreting follicles or tubuli developed from the lower excretory part of the intestine, like the renal organs of vertebrated animals, and these structural analogies have been confirmed by their chemical products, by the uric and lithic acids discovered in their secretions. These simple tubuli uriniferi pour their secretion into the cloacal part of the intestine near the anus, and in some of the coleopterous insects, as in ditiscus, there is a distinct small vesicle or urinary bladder into which one or two renal tubes convey their secretion, before opening into the terminal part of the intestine. The renal tubuli were pointed out by Treviranus in the iulus among the myriapods, they have been detected in some of the crustacea, as the pagurus, and they are seen in the spiders among the arachnida. The urinary organs, like other glands of mollusca, have seldom the form of elongated isolated tubuli, as they have in the articulated tribes, but generally present the form of short wide secreting sacs, opening near the anus or the genital organs. Such sacs are seen in many conchiferous mollusca, situate in the dorsal part of the body below the heart, and opening by two short ducts along with the oviducts, near the anus; these are often charged with earthy particles, and have been generally considered as destined to secrete the calcareous matter of the valves. In several of the terrestrial and freshwater gasteropods breathing atmospheric air by pulmonary sacs, uric acid has been detected in the secretion of a small excretory gland, laminated internally, filled with solid

granules, and opening near the anus, and which thus presents a close analogy to the renal organs of higher animals. The muciparous gland of the turbinated testaceous gasteropods, pouring out so copious a secretion under the mantle, near the anus, may perform a similar office, and also the glandular sac opening near the anus in the doris and some other naked species. The poison glands of scorpions and insects, the glands for the deep-coloured excretions of certain gasteropods, the anal ink-glands of cephalopods and the muciparous glands of their oviducts, have likewise some analogies to urinary organs.

In the vertebrated classes, no organs are more constant than the two essential urinary glands, the kidneys, and the more accessory urinary bladder is one of the most variable and inconstant. The urinary organs are generally of larger size, and of a simpler internal structure, in those animals which have a limited extent of respiration, so that their bulk is commonly in the direct ratio of that of the biliary organs. The urinary organs of vertebrata, like their genital organs, are developed in the embryo from the cloacal end of the alimentary canal, and in all the oviparous tribes, they continue in the adult state to communicate directly with that cavity. The kidneys of *fishes* have a lengthened lobulated form, extending along the sides of the vertebral column as far forwards as the cranium, exterior to the peritoneum, and behind the air-sac. In their elongated form, and in their proximity to each other along the median plain, as well as in their lobed structure, and in the parallelism of their component tubuli uriniferi, they resemble the embryo-state of these organs in mammalia. They extend forwards above the heart and branchiæ, and backwards into the pelvic cavity behind the anus, bound to the sides of the bodies of the vertebræ by the peritoneum, separated from each other by the interposed vena cava, and by the two ureters which run along their whole extent, as narrow tubes, without forming a distinct enlargement or pelvis. The great size of these emunctories of the aqueous part of the blood in fishes, may have relation to their aquatic habitat, and the quantity of fluids constantly taken with their food. The kidneys consist of subdivided ureters, the tubuli of which are variously disposed, and produce, by their subdivisions and convolu-

tions, the lobulated exterior so constant in the oviparous vertebrata. The secreting surface of these ducts is thus greatly extended for the reception of a larger distribution of renal capillary arteries and veins over their parietes, and the different modes of distribution of the blood-vessels in the interior of these organs in the different classes, contributes to the differences perceptible in the intimate texture of the kidneys, as of other glandular organs. The tubuli uriniferi are almost always long, cylindrical, narrow, and more or less tortuous in the adult lobules of the kidneys of the plagiostomi, and the higher osseous fishes, and more short, straight, parallel, and wide, in the earlier stages of their development, and in the lowest cyclostome species. Each lobule of the adult is composed of the tubuli proceeding from a single branch of the common duct or ureter, and appears, in the embryo, to consist of a single lamina of the formative blastema. The primitive vascular blastema of the embryo divides into laminæ, and each lamina developes a cluster of tubuli, which open by a common orifice, or short duct, into the cylindrical narrow ureter extending along the whole kidney. The group of tubuli uriniferi, composing a renal lobe, are held together by the remaining portion of the soft formative blastema. The blastema at first extends undivided on the median plain, along the middle of the back, between the mucous and serous layers of the embryo; a duct for each kidney is, at length, perceived extending through it longitudinally, and giving off lateral tubuli in its course, which develope through the substance of the lobules.

In the rays and sharks, the kidneys are composed of long, fine, very tortuous and convoluted tubuli, which open separately along the course of the ureter, and in the early embryo, they appear, as in higher classes, to be accompanied with a corpus Wolffianum, composed of very minute convoluted tubuli. In the torpedo marmorata, the kidneys form two lobulated organs extending along the outside of the ureters, and consist of large tubuli, about $\frac{1}{10}$ of a line in diameter, long, and remarkably convoluted like the tubuli seminiferi of mammalia. In many of the long, equal, contorted tubuli, forming the entire mass of the kidneys in the cyprinus carpio, Muller observed a distinct dichotomous division, at some distance from their closed extremities, preserving, however, as usual in

tubuli uriniferi, the same diameter throughout their entire course. The secretion of all the tubuli of each kidney is poured directly into the long narrow ureter, which, without forming a pelvic enlargement, and often without forming a urinary bladder, opens into the cloacal termination of the intestine, posterior to the rectal opening, and posterior to the genital openings, whether male or female, as in the embryos of higher vertebrata. Frequently, however, a urinary bladder is developed, which is comparatively small in fishes, its orifice then receives the terminations of the two ureters, and it opens by a short wide passage at the back part of the cloaca. The long narrow kidneys of many osseous fishes are approximated and more or less united on the median plain, without any anastomosis of their internal tubuli. In the plagiostome fishes, the kidneys are smaller and shorter, as in chelonian and other reptiles, and the ureters enter, as usual, with the vasa deferentia into a common short urethral passage, without forming a urinary bladder. The kidneys of fishes thus already present a very large secreting surface for the distribution of capillary blood-vessels, which are always much more minute than the tubuli on which they spread, as in other secreting organs. The numerous arteries which supply the renal lobes of fishes, come off directly from the trunk of the descending aorta, or from the intercostal arteries which are given off from its sides, and the renal veins mostly enter the vena cava, as it passes forwards between the lobes of these organs. The venous blood distributed through the lobes of the kidneys, by the branches of the great superior spinal vein, is received also by the vena cava, thus forming a renal portal circulation.

The kidneys in *amphibia* are less elongated and less lobulated in form than in most fishes, and the urinary bladder is of greater size and more constant in its occurrence. These glands originate early in the embryo, before the genital organs; they are developed more towards the dorsal and pelvic portion of the trunk than the corpora Wolffiana, and in the adult state they neither extend forwards to the cranium, nor backwards to the posterior end of the abdominal cavity, as they do in most fishes; so that the ureters have here a longer free course before reaching the back part of the cloaca, where they open at the sides of the wide orifice of the large urinary bladder. They are at first, as in fishes, narrow, flat,

approximated laminæ, extending longitudinally along the whole extent of the abdomen, under the vertebral column, and from the periphery of the organ towards the lateral portion of each tube or ureter, numerous minute tortuous tubuli uriniferi are developed to extend the secreting surface. Their structure much resembles that of the corpora Wolffiana of birds, which were thought to be deciduous kidneys, but the kidneys are here developed much posteriorly to the situation of these remarkable deciduous glands. The kidneys retain their primitive fœtal condition to a much later period in the tritons than in the frogs and toads, and their adult form is more elongated in the perennibranchiate species, as the *proteus* and *siren*, than in those which lose the gills. The closed vesicular terminations of the tubuli are perceptible around the periphery of the soft vascular blastema, earlier than the narrow tubular necks by which they communicate with the ureters, as the development proceeds from the circumference to the centre of these organs, and the development of the ureters appears also to proceed from their renal ends backwards to their open cloacal extremities. The form of the kidneys is more elongated and narrow in the *cæcilia* and *triton* than in *salamandra* and the anurous species, and the urinary bladder of *cæcilia* is bilobate in form, like that of other caducibranchiate amphibia. The urinary bladder has a simple and elongated form in the species which retain the branchiæ, as the *axolotus*, *siren*, and *proteus*. The tubuli are unusually large in the adult *proteus*. The dichotomous division of the tubuli uriniferi, near their closed ends, has been observed by Huschke in some of the amphibia, and also vesicular peripheral terminations, which latter are generally confined to the earlier stages of the development of the tubuli. The small round corpuscula Malpighiana turgid with red blood, are already abundant and conspicuous in the texture of the kidneys of amphibia, as in higher classes.

In the ophidian *reptiles*, as in fishes and birds, the urinary bladder is very rarely developed, and the ureters terminate as usual, directly and separately in the cloaca. The kidneys of serpents, like most other organs of the body, partake of the elongated form of the trunk; the left is situated farther backwards than the right; they are surrounded entirely with

peritoneum, and suspended freely in the cavity of the abdomen, to allow of greater motion of the vertebral column with safety, where there is yet no fixed sacrum. They have a deeply lobulated or folded structure, consisting of a long series of flat imbricated tortuous transverse lobes, or regular sinuous folds of their exterior tubulated portions, resembling externally so many small kidneys pressed closely together. The contorted and convoluted tubuli composing each of these lobes, pour their thick white viscid secretion, consisting chiefly of uric acid, by a single orifice into the common ureter, without forming a pelvic enlargement, and without the calices developed in the more concentrated forms of the kidneys of mammalia.

The narrow tubular ureters follow along the inner margin of the kidneys, receiving successively the short wide common ducts of all the separate lobes, and open by distinct orifices into the back part of the cloaca, as in other oviparous vertebrata, whether provided with, or destitute of, a urinary bladder; sometimes, however, a small vesicular dilatation is formed on each ureter before it opens into the cloaca. The blood-vessels penetrate from the exterior of the kidneys between the lobes, and appear to have been mistaken by Huschke for tubuli uriniferi ramifying through the lobes. The affinity of the anguine serpents to saurian reptiles, so obvious in most parts of their structure, is seen also in the presence of a urinary bladder in these species, which is of considerable size in the pseudopus; and the two short kidneys of the anguis are placed on the same transverse plain of the body, as in higher reptiles. The small white tortuous tubuli uriniferi preserve the same size and diameter throughout the substance of each lobe, and the same tortuous diverging course to their periphery, so that there is yet no distinction of cortical and medullary portions of these organs, as is seen in the kidneys of mammalia. In the long narrow kidneys of the embryo, the tubuli are short, cylindrical, and straight, and extend separately from the ureter, through the soft blastema, with little regularity in their arrangement or in their course; they commence in the embryo earlier than the suprarenal capsules, near to the cloacal end of the trunk, on the dorsal side of the corpora Wolffiana, as two narrow white opaque bands of blastema, along the inner edges of which, the ureters and the rudimentary tubuli make their

appearance. Their distance from the cloaca increases, the ureters elongate, especially that of the right side, a lobulated or convoluted surface is developed, the ureters open into the cloaca, close to the ducts of the deciduous kidneys or corpora Wolffiana.

In the saurian reptiles there is more generally a urinary bladder, and the kidneys are less elongated, and situated farther backwards in the pelvic region of the trunk, than in ophidia. In the crocodiles, however, and some others, where there is no urinary bladder, the ureters open separately into the dorsal part of the cloaca, as in birds and many inferior vertebrata. And even where there is a urinary bladder in the sauria, the ureters do not open directly into its cavity or fundus, as they do in most mammalia, but into the dorsal part of the cloaca near the neck of the bladder, as is seen likewise in fishes amphibia and chelonia. The great size of the urinary bladder in these animals results from its containing the entire allantois, which is not protruded from an external umbilicus, nor constricted and obliterated to form a urachus as in mammalia. The kidneys of the crocodilian sauria are surrounded with tortuous superficial folds, and appear more deeply lobulated externally, like those of serpents, and from the ureters sending off numerous lateral ducts, they are more complicated in the internal arrangement of their tubuli, than in the lizards. Their tubuli uriniferi, however, do not form tortuous groups arising from short wide primary ducts, in each of the several lobes, as in serpents, but diverge regularly in straight radiating lines from around a central wide duct, which traverses the whole extent of the axis of each lobe; so that a vertical section of a part of one of the lobes presents a pinnate appearance, with parallel straight tubuli extending to the periphery from the central duct. The kidneys are more developed at their anterior part in some of the lizards, as they are in birds, and taper backwards to their posterior ends, being shorter in sauria than in ophidia, and longer than in chelonian reptiles. In the embryo, the kidneys are more elongated, as in serpents, and their short simple tubuli extend directly from the side of the ureter, without indication of the lobulated structure seen in the adult lacertæ.

The kidneys of chelonian reptiles have a more concen-

trated and shorter form, and are less distinctly lobulated than in most inferior vertebrata; their surface presents a convoluted appearance, as in crocodiles, from the tortuous forms of their component lobules. The tubuli uriniferi are more tortuous in their course in the chelonian than in the crocodilian reptiles, but arise in a similar manner from the ramified ureters. Their urinary bladder is of greater size than in any other vertebrata, which accords with their succulent vegetable nutriment and their limited cutaneous perspiration; generally it is partially divided into two, and sometimes into three lobes at its upper part. Like the respiratory allantois of the fœtus of higher classes, it is a great follicular or hernial development from the cloacal part of the intestine, and although, as usual in oviparous vertebrata, the ureters do not terminate directly in it, but behind its cloacal orifice, uric acid is found in its viscid contents, as in the similar large urinary bladder of the batrachian animals.

The kidneys of *birds* are still constantly and deeply divided, especially at their posterior ends, into numerous lobes of considerable size, covered on their ventral surface only with peritoneum, and lodged immediately behind the lungs in the deep fossæ along the sides of the sacrum. They are elongated in form, diminishing in size from before backwards, constricted in their middle, symmetrical, placed between the same transverse plains of the body, deeply sulcated on their dorsal surface by the transverse processes of the sacrum. The component lobes are most numerous and distinct in the ostrich, and least apparent in some of the palmipeds, as the pelican. The largest anterior lobe of each kidney receives a distinct renal artery from the trunk of the aorta, and the smaller succeeding lobes receive branches from the femoral arteries, or from the sacra media prolonged from the aorta. The surface of the lobes, when closely examined, presents a convoluted appearance, as in many reptiles, from the tortuous distribution of the small lobules, formed by the shut ends of the ultimate tubuli uriniferi, as shown by Ferrein, and tufts of these tubuli end in small calyces, as in mammalia. The simple narrow ureters collecting the secretion from the renal lobes, and extending along the ventral and inner surface of the kidneys, without forming a pelvis, open directly into the dorsal and lateral part of the cloaca, by two prominent

papillæ, and, there being no urinary bladder in birds, the urine, containing a large proportion of urea with little aqueous constituents, is mixed with the other excretions in the cloaca. The openings of the ureters thus preserve the same relative situation as in reptiles and lower vertebrata. But in the ostrich, which presents so many other affinities with the mammalia, the two ureters open at the lower margin of the large cloacal cavity, which allows the secretion to accumulate as in a distinct bladder. The bladder, indeed, in its most normal form, is only a development of the cloacal part of the intestine, and the want of a urinary bladder in adult birds, is due to the extent of obliteration of the allantois and urachus originally continued from their cloaca. The minute cylindrical uriniferous tubuli, much larger than the capillary blood-vessels, and directed in a pinnate manner to the surface of the renal lobules, leave perceptible interlobular spaces for the blood-vessels, as in other glands, and the small sanguineous vesicles, or corpuscula Malpighi, are seen on these vessels in the tissue of the organ, as in mammalia. The larger branches of the uriniferous ducts unite to open by prominent papillæ into the ureters, and small calices were already detected by Ferrein in the pigeon, and are seen in the kidneys of the cassowary, the falcon, the pintado, and other birds.

The kidneys of birds first appear in the embryo as a soft transparent, almost homogeneous mass, in which the convoluted and foliated structure is gradually evolved, and the extremities of the uriniferous tubes which compose the lobules become perceptible in the periphery of the vascular blastema. For some days after escaping from the egg, in the larger birds, the delicate convolutions on the surface of the renal lobes, and the elegant pinnate arrangements of the ultimate tubuli, are beautifully manifested to the naked eye, by means of the natural secretion of white inspissated urea which fills and distends all these parts; but by immersion in alcohol, this beautiful appearance is soon effaced, by the uniform whitening of the whole surface. These organs are preceded in their development by the two elongated follicular glands, the corpora Wolffiana, the ducts of which proceed likewise along with the ureters to the cloaca. The deciduous corpora Wolffiana, composed of simple tortuous follicles proceeding transversely from their common marginal duct, and

extending along each side of the vertebral column, precede much the development of the kidneys, and disappear before the bird escapes from the ovum: they are more connected with the evolution of the genital glands, the testes and ovaria, than of the urinary organs, in the classes where they are observed. As in other glands, the tubuli of these deciduous bodies appear at first as pedunculated peripheral vesicles, which become gradually elongated and constricted to form straight narrow tubes, and, at length, long narrow tortuous and interwoven tubuli extending to the interior edge of the organ from the exterior marginal duct. Their structure resembles that of the kidneys of amphibia, but they are not organically connected with the urinary tubuli, and appear to assist in the development of the genital glands.

The urinary organs of *mammalia* generally present a more compact and simple external form, and a more extensive secreting surface by the minute divisions and the compact arrangements of their tubuli, than in lower vertebrata; they eliminate a larger proportion of the aqueous constituents of the blood, and they are always provided with a distinct urinary bladder. The lobed condition of the kidneys, so constant in lower classes, is still, however, observed as a normal adult character in many of the inferior mammiferous tribes, as in the cetacea, many ruminating and pachydermatous herbivora, the slow-moving plantigrade carnivorous quadrupeds, and in the amphibious mammalia and the otter. In the higher tribes, the kidneys pass early from the primitive lobulated condition to a more concentrated form, by the union of the lobes into a single compact organ, which generally presents internally a distinct cortical and medullary portion, resulting from the straight and parallel course of the minute tubuli in the central part, and their tortuous interwoven course in the exterior portion. These two portions are alike perceived in the separate renal lobes of the human fœtus, and in the component lobes of the adult lobulated kidneys in lower mammalia. The right kidney is generally more advanced in the trunk than the left, and impresses the liver; they are covered only on the ventral surface with peritoneum; they present a depressed and rounded form more or less elongated in different species, and they are largest

and most divided into lobes in the aquatic and the larger terrestrial forms of this class. In several of the cetacea, there are more than two hundred deeply isolated lobes in a single kidney, but in the monotrema, they are united into a simple compact organ; in the lobulated kidneys, the number of papillæ and infundibula corresponds with the number of lobes, but in the compact forms of the organ, the number of these conical tufts of tubuli is often reduced to a single papilla, and the entire pelvis to a single calyx. The relative development of the cortical and medullary portions, varies as much as the outward form of the organ in different mammalia. The structure and relations of the straight and tortuous tubuli uriniferi of the simple and lobulated kidneys of mammalia and lower vertebrata, and the connections of the small round vascular corpuscules with the arterial branches, were already investigated and described by Malpighi.

The kidneys of mammalia, as of lower vertebrata, are preceded in the embryo by the corpora Wolffiana, composed each of elegant series of simple transverse tubuli opening into a common longitudinal duct, which extends along the outer margin of these deciduous glands and terminates in the cloacal end of the intestine; these bodies are interposed between the situations of the renal and genital glands, they are most developed long before the middle of fœtal life, and they have entirely disappeared before birth. The kidneys appear at first as consisting each of a congeries of minute tortuous follicles radiating to the periphery of a small round soft gelatinous blastema, and terminating around the exterior surface of this primitive mass in minute closed pyriform sacs, like the vesicular terminations of the bronchial tubes of the lungs or of the early tubuli of most other glands. The peripheral terminal vesicles diminish in size and disappear, as the tubuli become lengthened, tortuous, and interwoven, and there is no trace of distinction between cortical and medullary portions in the interior, nor of lobes on the surface. The tubuli in the central part of the kidney become, at length, more straight and parallel, and grouped into conical fasciculi, which compose the medullary portion, while the tortuous interwoven peripheral parts of the tubuli form the cortical portion of the organ. These conical groups of

straight converging tubuli meet at their open extremities, and terminate, as shown by Malpighi, in prominent papillæ, which are surrounded by calyces opening generally, by infundibula, into a common wider receptacle, or pelvis, from which the ureter commences. The tubuli often divide dichotomously, both in the medullary and the cortical part of the kidney, without changing their diameter. The development of the ureters in the embryo, begins from their renal ends and proceeds downwards, being at first solid, then tubular, then opening into the bladder, which, in some abnormal cases, they do not reach. The urinary bladder is developed from the cloacal end of the intestine, as the peduncle of the allantois and the urachus, but its early communication with the alimentary canal is at length entirely cut off in most mammalia, by the separation of the rectal portion of the intestine above from the uro-genital canal below. In the monotrema, however, they continue to communicate, as in reptiles, through the whole of life.

Many internal secreting glands already considered, may likewise be viewed as partly internal excretory organs. The internal tubuli and cells of the lungs, by the carbonic acid and aqueous part of the blood which they so largely climinate from the system, may be regarded as presenting an extended internal excretory surface; and from the composition and functions of the bile, the tubuli of the liver may be viewed nearly in the same light. The various kinds of odorous and poison-glands at either end of the alimentary canal, and even the muciparous glands throughout its entire course, have partly an excretory function. The surface of all mucous membranes lining internal ducts and cavities which communicate externally, and serous membranes lining closed cavities, even the interior lining of blood-vessels, by constantly excreting and detaching globules, cytoblasts, or scales of epithelium, may also be considered as exerting an excretory function on the circulating fluids of the body.

SECOND SECTION.

External Organs of Excretion.

As the larger and more complex internal excretory organs are developed from the common mucous lining of the digestive canal of animals, the smaller and more numerous external forms of these organs are developed from the cutaneous covering of the body. The naked surface of the skin in most of the lowest animals, being both respiratory and secerning, may likewise be regarded as a general excretory surface, and the various forms of extravascular scales, shells, and other epidermic materials, poured out as nuclei or in a fluid state from its capillaries, and growing or concreting into granules, cells, or cytoblasts, have also a close analogy to excretions. The subcutaneous muciparous glands so large and complex in fishes, and so numerously spread over the naked surface of amphibia, and various other cutaneous glands of higher animals, eliminating materials little subservient to individual nutrition or to the race, are partly excretory in their function. The cutaneous glands most special and distinct in their excretory function, and the product of which is most analogous to the urine of the kidneys, and the carbonic acid and halitus expired from the lungs, are the small, simple, convoluted, *sudoriferous follicles*, or sweat-glands, perforating the epidermic layers, and so numerously spread over the entire surface of the body in the warm-blooded vertebrata. The innumerable minute ramified sebaceous glands, which pour their oily secretion, by distinct ducts, into the wider cutaneous follicles for the hairs, to lubricate and protect the skin and its epidermic developments, may likewise be considered as partly cutaneous emunctories, eliminating the oleagenous materials of the blood; so that these external forms of excretory organs become almost essential constituents of the cutaneous or tegumentary parts of animals.

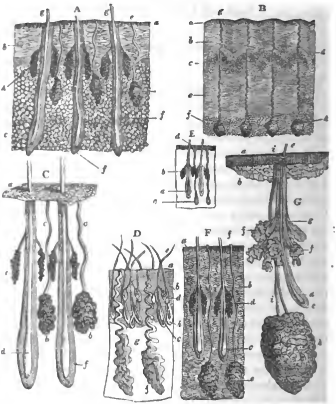
CHAPTER EIGHTH.

TEGUMENTARY ORGANS.

THE animal body being an aggregate of numerous complicated and delicate apparatus, nicely adjusted to the various mechanical and chemical functions necessary for the support of life, is always protected externally from the action of the surrounding elements and from accidental injuries, by some common investing *tegumentary organs*. These external investments consist generally of a compact reticulate fibrous, elastic, highly sensitive and vascular *cutis*, corium, or true skin, and a more superficial, extravascular, insensible, scaly *cuticula*, epidermis, or scarf-skin; and to these are often superadded various forms of horny scales, plates, spines, hairs, feathers, or other accumulated epidermic exudations from the vascular secreting surface of the true skin. The cutis or true skin of the higher classes of animals, developed, like the osseous, the muscular, and the nervous systems, from the exterior or serous layer of the germinal membrane of the ovum, continues in the adult as the most exterior of the sensitive and vascular tissues of the body. It is not only the seat of the sense of touch, by the innumerable sensitive vascular and erectile papillæ developed over its surface, but likewise of various secretions from myriads of minute glands imbedded in its substance, and whose ducts traverse in a straight or tortuous direction its fibrous tissue. These ducts open on the surface of the epidermis, as seen in the annexed views (Fig. 146.) from Gurlt, of the simple *piliferous follicles* (146. A. C. *f. f.*) and the more complex *sebaceous glands* (146 A. *h.* C. *e.*) and *sudoriferous glands* (146. A. *d.* C. *b. b.*), communicating with the exterior surface of the skin (146. A. B. C. *a. a. a.*). Besides the piliferous follicles, the sudoriferous and oil-glands, and the numerous capillary blood-vessels, nerves, and lymphatics which every where permeate the fibrous texture of the skin, it has been considered as the seat

of a distinct *chromatogenous* apparatus for secreting the carbonaceous colouring matter or pigment-cells of the

Fig. 146.



epidermic scales, and of distinct *blennogenous* glands for secreting the constituent matter or cytoblasts of the epidermis itself.

Resting immediately on the subcutaneous cellular and adipose substances (146. A. *c*. B. *f*.) is the inferior fibrous reticulate layer (146. A. *b*. B. *e*.) of the cutis, of very variable thickness in different animals, permeated by the subjacent cellular substance, and in which are generally imbedded the minute oil-glands (146. A. *h*.) of the piliferous follicles (146. A. *f*.) which contain the hairs (146. A. *g*.). The exterior papillated layer (146. B. *c*.) of the cutis is more thin, compact

and homogeneous, covered with sensitive papillæ, traversed by the piliferous follicles, the hairs, and the long tortuous ducts of the sweat-glands (146. B. *h.*), and is in contact with the rete mucosum (146. B. *d.*) of Malpighi, or the soft inferior layer of epidermis. The prominent conical sensitive papillæ of the surface of the skin are most developed on the naked palmar and plantar surfaces of the hands and feet in the soft-footed animals, as seen on the palm of the human hand (146. B. *c.*); and on many parts of the skin they are not perceptible, as on the human scalp (146. A. *a.*).

The *sudoriferous* glands have been detected by Gurlt in all parts of the surface of the body, placed generally deeper than the piliferous follicles, and imbedded in the subcutaneous cellular substance. They are large and obvious to the naked eye, beneath the soft skin of the genital region of the horse (146. G. *k.*), and nearly as large under the plantar surface of the dog's foot, and they are of smaller size in other parts of the hairy skin of the horse (146. F. *e.*), and in the skin of the hog (146. C. *b.*). They are small and round in the palm of the human hand (146. B. *h.*), more elongated in the human scalp (146. A. *d.*), minute, simple and uniform under the skin of the ox (146. E, *c.*), and under the hairy skin of the dog, and they are very large and equal under the thin soft skin of the sheep (146. D. *f. g.*). They consist each of a single transparent long follicle, more or less convoluted into a mass at its closed extremity, like the tubuli of the testis, and their single tortuous duct, lined with epidermic cytoblasts or epithelium, opens by a dilated conical orifice on the surface of the skin (146. A. *e.* E. *d.*), or continues its spiral windings (146. B. *g.*) through the strata of thickened cuticle (146. B. *a. b.*).

The small elongated racemose clusters of minute transparent white follicles, composing the conglomerate *sebaceous* glands (146. A. *h.* C. *e.*), are situate more superficially in the texture of the skin, than the piliferous follicles (146. A. C. *f. f.*) or the sudoriferous glands (146. A. *d.* C. *b.*), which extend more deeply into the subjacent cellular substance. The sebaceous glands and the piliferous follicles occur over most parts of the body, excepting on the naked palmar and plantar surfaces of the hands and feet in man and carnivora, where neither are observed. In some naked parts of

the skin the sebaceous glands abound without piliferous follicles, but the piliferous follicles, when present, are always accompanied with one or more, generally with two, sebaceous glands. The numerous small follicles composing each of these conglomerate sebaceous glands, communicate generally with a single duct, sometimes with several ducts, which open directly into the piliferous follicles, where they are present, or on the surface of the skin in many hairless parts; and these glands vary in magnitude generally according to the size of the hairs they accompany, but they are very minute in the hog (146. C. *e.*) which has large hairs (146. C. *d.*).

The *piliferous* follicles (146. A. C. *f. f.*) are appropriated to the development of the hairs, and to the reception of the oily secretion of the sebaceous glands. They are elongated simple sacs, widest at their deeper closed extremity, and narrowest at their orifice, where they embrace closely the contained hair. They penetrate vertically through the skin to the subcutaneous cellular substance, and they correspond in size and form with the contained hair. They are prolongations of the vascular secreting surface of the cutis, and they receive the secretions of the sebaceous glands, which can be pressed out from their orifice. Like all the ducts of cutaneous glands, they have a distinct lining of epithelium, which can be drawn out entire, continuous with the epidermis, from the macerated skin of the fœtus, and coloured portions of the cuticle can often be distinctly traced into their cavity. The epidermic linings of these various small cutaneous ducts, appear as so many minute connecting fibres, when the cuticle is being gradually drawn off from the surface of the cutis.

The most exterior continuous tegumentary layer of animals, as of other organized bodies, is the insensible extravascular *epidermis*, poured out as granular nuclei in a fluid medium, from the reticulate, vascular, sensitive surface of the cutis, or secreted by its capillaries. Like most internal organized tissues, the exterior epidermic covering originates from minute cells, or *cytoblasts*, which possess, like entozoa, an independent means of growth, and undergo various changes in the course of their development; and all the different cuticular appendages, as hairs, spines, nails, hoofs, horns, feathers, and scales, are merely aggregations of the same epidermic cells. The epidermic *nuclei* when first formed, exhibit internally a granular struc-

ture, and are contained in a soft gelatinous connecting substance, a *cytoblastema*, which enables them to grow, and to detach concentric layers or enveloping cells from their surface. The exterior cells grow more rapidly than the contained nuclei which first developed them, and there are commonly minuter pigment-cells, like internal parasites, free in the contained fluid of these cytoblasts. The soft, round, loosely aggregated, newly produced, growing cytoblasts, forming the lower strata of epidermic cells, compose the *rete mucosum* of Malpighi, where the various hues of the contained pigment-cells, in all deeply-coloured animals, are most fresh and intense, and where the cuticular cells are still most agglutinated to the surface of the cutis. As the epidermic cells, by their own independent vitality, enlarge, and thicken in their parictes, the connecting gelatinous matter, or cytoblastema, disappears, they become contiguous, compressed, and polyhedral, and the nuclei are still perceptible towards the centre of the thus flattened cells, attached to their interior surface. In the outer strata of the epidermis, the cells are thin, empty, flattened disks, bleached, deprived of their colouring matter, compressed into a continuous layer, and they at length fall from the surface as dried, isolated scales, with their opposite parietes coherent, and with single persistent nuclei. The black pigment-cells of the cuticle of the tadpole, undergo remarkable changes of form, like a polygastric *proteus*, and they contain numerous, minute, parasitic, spontaneously moving cells, in their interior.

The epithelial cytoblasts of internal parts present similar phenomena of growth, development, and metamorphosis, to those of the exterior epidermis; they are seen on the lining membrane of the heart, in veins, on the chorion, the amnion, and on all mucous and serous surfaces; their form is sometimes lamellar, sometimes conical or cylindrical, and they often exhibit distinct vibratile cilia at their free extremity on mucous membranes. Cytoblasts abound in all secretions, they constitute the first rudiment of the ovum, and the globules of blood, milk, and other animal fluids; they give origin to capillary vessels, to cartilage, to the fibres of the lens, of the teeth, of cellular tissue, of nerves, muscles, and most other tissues of animal bodies. The primitive germinative nuclei often develope two or more concentric enveloping cells around each, these concentric spheres often coalesce and

unite to thicken the parietes of the general cell, two or more nuclei are often found within the same cell, and the nuclei generally retrograde in their development, or entirely disappear, when the cells they produce have arrived at their maturity.

The successive strata of epidermic cytoblasts are most accumulated, and retained, in a condensed form, on parts of the skin most exposed to pressure and friction, as on the palmar and plantar surfaces of the extremities, and on the whole surface of thick-skinned naked animals, as rhinoceroces, hippopotami, manati, and other pachyderma and cetacea. The difference of colours in the contained parasitic pigment-cells of the epidermic cytoblasts, which are most vivid and most lively in the soft, loose cytoblasts of the rete mucosum, gives rise to the varied hues of all the tegumentary parts of animals. In the interior even of these parasitic pigment-cells, are sometimes seen numerous other minute cells in active movement. The colour of the pigment-cells often varies in different parts of the skin, giving rise to corresponding differences in the colour of the hairs, spines, and other epidermic developments; their excess produces the intense colour of the rete mucosum of the negro, and other deeply-coloured animals; their deficiency produces the various tegumentary peculiarities of albinos; and the ephemeral existence of these coloured parasites, causes the outer strata of epidermis to be shed colourless, from the most deeply coloured skins of animals, as salamanders, serpents, and negros. The epidermis is already a thick layer on the palmar and plantar surfaces of the extremities in the early condition of the embryo, and the coloured parts of the teguments of quadrupeds are distinctly marked at an early period of the fœtus in utero.

The cytoblasts of the epithelium, at the exterior openings of mucous cavities, have mostly the same flattened form and stratified arrangement as in epidermis, as seen on the interior of the nostrils, the lips, the mouth, the tympanic cavity and the mastoid cells, and on the surface of the conjunctiva and cornea, where they were observed and described by Leuwenhoek, as forming a hundred strata of superimposed scales; but in most other parts of the mucous surfaces they present a conical or cylindrical form, are compactly

arranged with their long axes vertical to the surface on which they rest, and have often distinct vibratile cilia at their broad free end. The vibratile cilia of the epithelial cytoblasts, are larger and more extensively distributed in the fœtus than in the adult, as shown by Henle on the human epiglottis; and they are continued vibratile on the epithelium through the larynx, trachea, and the minutest ramifications of the bronchi, and the cells of the lungs, where the ciliated cytoblasts have the usual cylindrical form.

The epithelial cytoblasts continue cylindrical in the ducts of most glands, in the stomach, and along the whole intestine to the anus, where the epithelium abruptly unites with the flat-celled exterior epidermis, and they have the same cylindrical form in the interior of most of the uro-genital passages. In the female, however, the flat-celled epithelium lines the entire vagina, and the cylindrical cytoblasts with vibratile cilia, perceptible in the adult state, begin about the middle of the cervix uteri, and continue throughout the body of the uterus and along the Falopian tubes and their fimbriated terminations. The epithelium of serous membranes consists of flat cells, with a distinct central nucleus in each, and arranged in a tesselated form, as seen on the peritoneum, pleura, pericardium, tunica vaginalis testis, synovial membranes, and membranes of the brain. Vibratile cilia are more rarely observed on the epithelial cytoblasts of serous membranes, and exist on the lining membrane of the ventricles of the brain, and on the exterior peritoneal surface of the fimbriated ends of the Fallopian tubes. The epithelial cells detached from the parietes and ducts of secerning tubuli, and from other mucous surfaces, are observed isolated and mixed, like corpuscles, with the various secretions and excretions, as in mucus, saliva, lachrymal fluid, bile, and urine, and they appear to form the nuclei of morbid irritation, and the corpuscles of morbid secretions, in various pathological states.

Hairs, bristles, and spines are merely epidermic appendages, developed, like teeth, in highly vascular cutaneous sacs or follicles; they are formed by the successive aggregations of cytoblasts, and are gradually protruded from the piliferous follicles by the growth and elongation of their constituent cytoblasts, and by the addition of new layers to their ex-

panded, soft and hollow base, the apex and shaft of the hair, or spine, being formed before the bulb, like the crown of the tooth before its fang. They are continuous, at their base, with the epidermis lining the enveloping follicles; they are composed of the same cells or cytoblasts, which are commonly arranged in rectilineal series; and they generally present a more dense exterior laminated cortical part, inclosing a loose granular medullary portion. The component cytoblasts are more round and loose at the soft, dilated base of the hairs, as in the rete mucosum; and they are compressed, elongated, and more compactly united, in the denser shaft of the hairs. By the rectilineal arrangement of the component cytoblasts, the hairs possess a fibrous structure, and greater elasticity and strength, they are more permeable to the oily secretion of the sebaceous follicles, and they exhibit a filamentous decomposition, often seen in the spontaneous longitudinal fissuring of the human hairs. The soft dilated bulbs of the hairs, beneath the cutis, are alone developed, and are confined to their follicles, in the smooth-skinned piscivorous cetacea. But in the rough-skinned herbivorous species of these animals, the shafts of the hairs are partly protruded from their follicles, like short, hard spines, and are especially developed on the upper lip, as they are also in amphibious carnivora. The almost horny epidermic integument of the herbivorous cetacea, has long been compared to the continuous horny hoofs covering the piliferous follicles and their contained hair-bulbs, on the feet of solidungula and ruminantia.

Hairs are successively reproduced in the same follicles, when shed periodically in mammalia, or when forcibly *torn* from their cavities, like the teeth of crocodiles in their alveoli. The hairs of mammalia grow and enlarge in their follicles, and are gradually protruded through their constricted apertures, by the addition of successive layers of epidermic cytoblasts, lineally aggregated, to the hollow interior and base of their soft, white, expanded bulb, and by the enlargement of the individual cytoblasts. The constituent cells are connected together, as in other epidermic parts, by the remains of the soft adhesive cytoblastema, which originally afforded them nutriment. By the great elongation and compression of the cells as they proceed outwards from the bulb,

the shaft of the hair becomes much more narrow than the base from which it originates, and the fibrous structure is most apparent on the peripheral or cortical portion of the shaft. The fibrous composition of hair was described and figured by Leuwenhoek. The nuclei of the cytoblasts almost disappear, in the elongated cells forming, by their lineal aggregation, the ultimate filaments of hair; and the artificial separation of the constituent filaments, is rendered much more easy, by macerating the hairs in dilute muriatic acid, when they are seen to be disposed in a longitudinal, rectilineal and parallel order, from the bulb to the point of each hair. The filamentous structure and fibrous decomposition of hairs were familiar also to Hooke in 1667. The diameter of the ultimate fibrils of a hair is about the two thousandth of a line, and a human hair of one tenth of a line in thickness, has about two hundred and fifty fibrils in its mere diameter, and about fifty thousand in its entire calibre: so that these ultimate fibrils are finer than those of almost any other known tissue, from the great elongation and narrowing of their constituent cells, as they are drawn out into the shaft of the hair during growth; and hence the expanded bulb of the hair, where the cells are yet spherical and soft.

In the larger hairs, bristles, and spines there is generally a more compact, thin, dense cortical part, inclosing a loose cellular medullary portion, not perceptible in the human hairs; so that they more resemble the shafts of feathers destitute of lateral barbs. The highly vascular and sensitive hair-pulp in the long whiskers of carnivora, extends through the bulb into the shaft, and increases the sensibility of these parts, while it adds to their strength of attachment, and to their surface of increment. The nails and claws of mammalia and other vertebrata are composed of the same epidermic cells, and grow in reduplications of the skin forming compressed, curved follicles, like the cylindrical hairs and spines in their circular cavities. The successive strata of polygonal cells, which are most easily separable in the embryo and fœtus, are added, in lineal aggregations, to their covered base, and their compact, dense, free portion is gradually protruded from the compressed enveloping follicle. The constituent cytoblasts with their nuclei and fluid contents, are most distinct at the soft, white base, and at the inferior sur-

face of the nails, and become compressed, flattened, and compactly agglutinated together on the upper surface and the protruded part, where the stratified arrangement is most apparent, and where the nuclei and contents of the cells have mostly disappeared. Layers of cells are secreted and added along the whole inferior attached, concave, lamellated surface, to compensate for the flattening and thinning of the upper convex strata of cells, first added from behind and from beneath, and thus to preserve the equal thickness and strength of the nail at its free, exposed part. The nails being thus only the thickened epidermis of the parts which support them, they adhere in the same manner as epidermis, to the subjacent sensitive and vascular laminated surface of the cutis, by means of the soft, homogeneous, adhesive cytoblastema which envelopes, nourishes, and unites together the growing component cells.

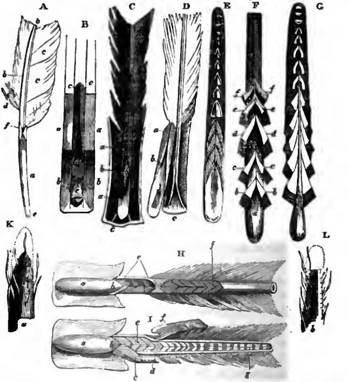
The anterior vertical portion of the hoofs of ruminantia and solidungula consists merely of a large curved nail, and the inferior horizontal portion, which is partially attached to the former along its anterior thick margin, is only the usual thickened epidermis, covering the lower surface of the toes. The vertical curved portion of the hoof, analogous to the human nail, embraces a large part of the anterior and lateral surface of the toe, is more deficient behind, and extends downwards beyond the plain of the inferior basilar plate, so as to defend the entire lower margin of the hoof, which is most subjected to pressure and attrition. In the feet of solidungula the entire anterior portion of the hoof is formed as a single investing independent nail, and extends beyond the inferior thickened epidermic plantar portion. The sharp, dense, compressed, curved claws of feline carnivora, are nails which almost invest the terminal phalanges of the toes, and have their base and its containing follicle supported by an osseous sheath; they are kept sharp at the point by the periodical shedding of their terminal laminæ. Even the permanent vaginiform horns of antilopes and other ruminantia, are formed and developed like conical nails around the tuberosities of the frontal bone, receiving their means of increment in their interior cavity and around their follicular base, like the tusk of an elephant, or the bill of a bird, a tortoise, or a cephalopod, or the conical shell of a gasteropod. And the solid nasal or frontal horn of the rhinoceros is

developed from the subjacent periostium, like a large hair from its follicle, or like the horny coverings of the papillæ on the plantar surface of the feet in carnivora; and it exhibits the same fibrous structure and filamentous mode of decay, as in other epidermic parts composed of recti-lineal aggregations of cytoblasts. In these various forms of epidermic developments, the polyhedral form of the compressed cells, their nuclei and fluid contents, and their lineal arrangements, are most apparent in their primitive soft condition in the fœtus, or in the recently formed portions in the adult; and in their subsequent metamorphoses their internal fluid and nuclei disappear, the empty cells become elongated or flattened, with their interior parietes contiguous, they are agglutinated into laminæ by the remains of the cytoblastema, and their conformable stratified superposition is rendered more distinct.

The feathers of birds, like the hairs of mammalia, are epidermic developments contained in cutaneous follicles; they are provided with their vascular secreting pulp, their hollow bulbous base of increment, and their solid exposed shaft; and like them, they are composed of extravascular organized independent cells, or cytoblasts, which were already figured and described by Hooke, and by Leuwenhoek, as composing the entire microscopic structure of the feather. Like other epidermic structures, feathers are first formed and most developed on those parts where they are first and most required, and their horny composition and tubular structure are those best adapted to combine strength with lightness. The strong diaphanous tubular empty quill (147. A. *a.*) in the adult bird, is deeply imbedded in the cutaneous penniferous follicle, as the point of attachment and of nutriment of the feather, and contains only a few dried remains of the primitive secreting pulp-cells. The tapering light elastic conical shaft (147. A. *f. b.*) is occupied internally with white dried aeriferous cytoblasts, which were described before the time of Leuwenhoek, and gives a firm support to the two unequal sides of the vane (147. A. *c. d.*). The vane is composed of barbs (147. A. *d.*) or laminæ placed vertically to afford the greatest resistance in flight, closely applied to each other, continued from the sides of the shaft, and connected together by barbules developed from each side of their dorsal or

exterior margin. The barbules again develope, from their margins, minute curved, hooked filaments, or barbulinæ, to complete this delicate structure for hooking together and uniting the barbs into a continuous membrane, as shown by Hooke, who carefully investigated, described, and figured this complex mechanism in 1667, and accurately compared each barbule, with its barbulinæ, to the structure of an entire feather. In most feathers the proximal part of the vane (147. A. *d.*) has its barbs and barbules long, loose and floating, so as to form a compact downy mantle next the skin of the bird, to retain the high temperature of the body. In the rest of the vane the barbs are more firm, straight, regular and united, to assist in flight, or to protect the body.

Fig. 147.



The parts of the feather, as shown by Dutrochet, Blainville, and F. Cuvier, are at first formed within a thick closed epider-

mic capsule (147. B.) embracing in its axis two concentric striated membranes, (147. B. *b. d.*), and a highly vascular, secreting, formative pulp (147. B. *d. e.*), and contained in a deep penniferous follicle. This exterior epidermic capsule, perforated below by the vessels and nerves of the organized pulp, elongates, opens above, and allows the newly formed parts of the feather to escape from the opening of the cutaneous follicle. This general extra-vascular enveloping capsule, (147. C. c.), is entirely composed of strata of large flattened cytoblasts, which grow by their independent vitality, are united by their cytoblastema, and give a necessary brittleness to the texture of this deciduous membrane. On cutting open the exterior capsule of the young feather, the two more delicate tonics are seen investing the pulp, and connected together by numerous septa; the soft, newly formed barbs, (147. B. *c. c.*) moulded between these septa, are thus found folded around the central organized matrix, being developed in a polythalamous cavity filled with the granular secretion of the vascular pulp. The pulp developes a series of superimposed conical capsules, and traverses their axis in a continuous canal, as seen in the annexed figures from F. Cuvier (147. E. F. G.). The dense tubular elastic quill is formed by the meeting of the edges of the exterior horny dorsal lamina of the shaft, after the completion and convergence of the two sides of the vane; and an exterior opening, or upper umbilicus, is left at this point for the admission of air to the interior and cells of the quill and the shaft. The membranous cells (147. K. L.), disengaged from the distal extremity of the organized pulp, and occupying at first the cylindrical cavity of the folded barbs, are successively detached, exposed, and lost by the unfolding of the barbs, and the rest are confined and retained, dried, and collapsed, within the closed tubular quill, after the shaft is completed.

The large polyhedral pith-cells of the growing shaft contain, at first, a fluid substance; they are provided each with a distinct nucleus adhering to its inside, and within the nuclei are seen one or two comparatively large nucleoli; the cells are easily separable from each other; they have firm exterior parietes, and in the adult state, like the few large cells of the quill, they contain only air, and have nearly lost all traces of their nuclei. As the internal constituent cytoblasts of the shaft-

pith are successively derived from around the apex of the contained central organized pulp, they are most developed towards the outer dorsal convex part of the shaft, and are smallest near the central cavity, which is indicated only by an inferior longitudinal groove in the adult expanded feather. More nearly in contact with the formative matrix, indeed, are found mere granular nuclei, contained in a fluid cytoblastema; and these organized, though extravascular, independent nuclei, pass through the ordinary phases of development and growth, seen in other epidermic and epithelial cytoblasts. These epidermic cells composing the white friable corky pith of the shaft, were accurately described by Hooke in 1667, and Leuwenhoek described and figured the cytoblasts, or globules, composing the barbs.

The formation of a distinct, thin, dense, interior epidermic layer, in the concavity of the growing shaft, and around the exterior surface of the secreting matrix (147. H. I. *a. b.*) completes the inferior concave surface of this part of the feather, and prepares for its gradual protrusion, with the perfected and unfolding barbs continuous with its sides. On opening the organized pulp (147. D. *b. b.*), innumerable vessels, turgid with red blood, are seen forming a continuous network over every part of its interior parietes, and their trunks are observed entering the convex conical part of its base where a terminal opening or inferior umbilicus is left in the adult quill (147. A. *e.*). The outer strong elastic layer forming the dorsal fibrous covering of the shaft, between the outer ends of the septa, or barbiferous cells, is early developed, and originates from cytoblasts, which undergo changes very similar to those which give origin to the minute fibres of cellular tissue. From their primitive rounded form, these cells are observed to elongate, to become flattened, and gradually to subdivide each into numerous longitudinal fibres; their nuclei disappear, their parietes become absorbed or fissured, and they at length constitute the compact horny fibrous covering of the dorsum of the shaft, and the entire parietes of the quill, which is merely a cylindrical continuation of that portion of the feather. The inferior grooved surface of the shaft is covered by a similar deposition of granular independent animated cells, with their nutrient fluid cytoblastema between the lower ends of the grooved barbiferous septa, or compli-

cated cavities in which the apparatus of the vane is moulded. On examining even the minutest parts of the barbules of feathers, the constituent elongated compressed angular cytoblasts, compactly and symmetrically arranged, and provided with persistent central nuclei, are distinctly perceptible. A second shaft, furnished with all the apparatus of the vane, is generally more or less developed from the superior umbilicus or distal opening of the quill, and this supplementary shaft sometimes, as in the emeu, equals in length that of the primary feather. The rudiment even of a third shaft is sometimes developed from the feather, and the entire plumage of a bird is sometimes renewed once or twice in a single season. But notwithstanding the endless diversity of form and the intricate structure of these organs, and the remarkable changes they undergo during their development, growth, and moulting, they present only a more complex form of the ordinary insensible, extravascular, epidermic tissue, forming the exterior integument of most organized bodies.

In the simple organizations of the lowest animals, the difference is less marked, between the exterior cutaneous and the interior mucous coats, and between the epidermic and the epithelial developments they form on their surface; and as most of them are inhabitants of an aquatic medium, their epidermic covering generally retains the soft condition of a rete mucosum, or of a mucous deposit, as seen in the naked forms of radiated, helminthoid, and molluscous animals. It is shed in flocculi from poriphera, and in larger pellicles from the surface of many zoophytes, as lobularia, and its constituent cytoblasts were observed by Gäde in acalepha. In many vaginated forms of polygastric and polypipherous animals, it composes a firm, elastic, often articulated, almost horny sheath, over the entire surface of the true skin; and in the entomoid and testaceous animals, it becomes consolidated by the addition of various earthy materials, to compose their enveloping extravascular skeletons. Its granular nuclei are constantly pouring from the vascular secreting surface of the cutis, its condensed accumulations adhere to the skin by means of the cytoblastema, and these accumulated epidermic masses are periodically thrown off from the body in the articulata, but are consolidated, collected, and permanently retained in the testaceous mollusca and radiata. The resplen-

dent hairs of halithea, the setæ of annelides, and the agglutinating matter of their tubes, the down and hairs of larvæ, and those common on adult insects, arachnida, and crustacea, the byssus of conchifera, the horny opercula of gasteropods, the horny mandibles of cephalopods, the lingual spines of many mollusca, the gastric teeth of aplysia, the spines of the gizzard of insects, the gastric plates of bulla, and the animal matter of all testaceous coverings, may be considered as parts of the same epidermic or epithelial tissue, having the same extravascular and cytoblastic character, and the same organization and independent vitality.

The tegumentary organs of the vertebrata are closely related to the temperature of the body, and to the density of the surrounding medium, those of the warm-blooded classes being slow conductors of caloric, in order to preserve the high temperature of their body, and those of the cold-blooded being indifferent in their conducting power, as they are also in most invertebrata. The sensitive vascular skin of fishes, is thick, soft, gelatinous, and closely connected by tendinous intersections with the subjacent muscular system. The cuticle, as in the naked aquatic mollusca, forms a thin, soft layer; and by its periodical shedding, the lively colours of the inferior loose strata of cytoblasts, or rete mucosum, are allowed to shine more distinctly through the pellucid scales, and this increased brilliancy of colour is most marked at the spawning season. The imbricated scales of fishes, which are wanting in the cyclostome and very minute in the plagiostome species, but generally cover their surface, are consolidated by phosphate of lime, detected also in the hairs of mammalia; and they grow, like the human nails, or the wing scales of lepidopterous insects, by successive layers added by the squamiferous follicles of the cutis, in which they are fixed.

From the soft, thin, and granular condition of the newly formed epidermic and epithelial coverings of membranes, the secretion of glandular tubuli, and the respiration of pulmonary cells, or branchial laminæ, are easily effected through these coverings. And from the necessity for free respiration by the entire cutaneous surface of the body in the amphibia, their highly sensitive and vascular cutis is destitute of scales; it is covered only with a thin, soft epidermis, which is cast

rapidly and frequently, that of the frog and triton being apparently shed every month. Their copious exterior secretions, perhaps, also demand a higher cutaneous oxygenation and a thinner epidermic covering. The epidermis of the triton is shed in an entire piece, as in serpents. On the surface of the tough, thick, fibrous, papillated cutis of ophidian and saurian reptiles, the soft rete mucosum, composed of newly-formed cytoblasts, generally presents the most intensely and lively coloured pigment-cells, which fade or die before they are shed with the concrete outer layer of epidermis. As the apparent scales and scuta are only elevated papillæ or tubercles of the vascular secreting cutis, sometimes partially imbricated, the epidermis passes continuously over them, and is thus cast from the entire body without perforations or scales, and even from the united transparent eye-lids or conjunctiva of serpents, as from the compound eyes of articulata. The tortoise-shells, or epidermic plates, covering the osseous elements of the carapace and plastron of chelonia, are permanent accumulations of cytoblasts, formed in successive and increasing layers from the subjacent vascular periosteum, like the nasal horns of the rhinoceros, or the permanent vaginiform horns of ruminantia; and the limits of the successive layers of growth, are here commonly indicated by peripheral ridges on the exterior of the plates, as on the shells of conchifera and of gasteropods.

The sparkling and resplendent surface of most fishes, accords with the liquid element and its pebbled bed; the dull and sombre surface of most amphibia and serpents, accords with their concealed habitats; and the more lively colours of many climbing ophidia and lacertine sauria, are adapted to their arboreal life. The mutable colours of the chamælion, conceal it from its insect prey; the dark rough surface of crocodilian sauria, conceal them on the muddy banks of rivers, or among the decayed trunks of fallen trees; the dark dull surface of most terrestrial chelonia corresponds with their lurking and burrowing habits; the lustre, transparency, and mottled brown colours of marine turtles, pervading the whole substance of their large, permanent, epidermic plates, resemble those of the dark fuci, on which they rest and feed. The parasitic pigment-cells of epidermic cytoblasts, are little developed amid the snows and darkness of arctic regions, where

albino peculiarities are naturalized, as in the wild swan, the snowy owl, the alpine hare, the arctic fox, the polar bear. Dull and sombre hues best suit nocturnal animals, as moths and owls, rats and mice, bats and lemurs; and the darkest colours conceal the inhabitants of burrows and subterranean caves, as beetles, toads, and moles, and the huge inhabitants of the dark abyss, as walruses, seals, and cetacea. The most lively and varied colours, and the brightest metallic lustres, are developed in the diurnal species of tropical climes, as in parrots and cockatoos, humming birds, and birds of paradise; and the hues appear often to be regulated by those of the accompanying vegetation. The metallic lustre, so rare in mammalia, is splendid in the chrysochloris. The reddish-brown fleece of lions and pumas, caracals and tigers, and most feline inhabitants of the deserts, resembles the decayed leaves, or the light of the setting sun, or the sandy plains on which they lie in watch for their prey. So that the properties of these extravascular parts, have extensive relations to the internal economy of animals, and to surrounding nature.

The colours of the tegumentary parts of animals, depending upon living parasites in the body of the epidermic cells, are most distinct in the plump condition of these in the rete mucosum, and are alike obvious in the chick in ovo, on the fœtus in utero, in the developing feather yet concealed in its thick sheath and deep cutaneous follicle, and in the hairs of subcutaneous cysts, to which the chemical influence of light has never penetrated. Indeed the entire structure, properties, and forms of the tegumentary parts of organized beings, are regulated by laws as simple and uniform as those of the most essential organs of vegetative life, and they are most intimately connected with the living habits and the entire history of the species.